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A SURVEY OF PAST WORK ON RATES OF ADVANCE IN LAND COMBAT OPERATIONS

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19. ABSTRACT (continued)

The first phase was devoted to assembling as much of the existing statistical data on historical rates of advance as possible, and to computerizing the data. The second phase consists of a comprehensive survey and critical review of the literature to identify trends, omissions and gaps, and to provide a comparative analysis and assessment of its conclusions and findings. The third phase will consist of original statistical and other analyses of the assembled data. The fourth and final phase will involve reporting the results.

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RESEARCH PAPER

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A SURVEY OF PAST WORK ON RATES OF ADVANCE IN LAND COMBAT OPERATIONS

February 1990

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PREFACE

The 1989-1990 Secretary of the Army Fellowship awarded to Dr. Robert L. Helmbold calls for conducting an investigation into the distances, durations, and rates of advance of land combat forces. The work consists of four phases. The first phase was devoted to assembling as much of the existing statistical data on historical rates of advance as possible, and to computerizing the data. The second phase consists of a comprehensive survey and critical review of the literature to identify trends, omissions and gaps, and to provide a comparative analysis and assessment of its conclusions and findings. The third phase will consist of original statistical and other analyses of the assembled data. The fourth and final phase will involve reporting the results. The anticipated schedule is as follows:

<u>Phase</u>	<u>Anticipated Completion</u>
One	December 1989
Two	February 1990
Three	May 1990
Four	July 1990

This Research Paper surveys noteworthy quantitative past work on the principal factors governing rates of advance. It is the first paper to appear under this Fellowship, and we anticipate it will be followed by others on the rate of advance data and its quantitative analysis.

We are not aware of any other work that covers this area in the depth to which this Research Paper does. Thus, it is a useful basic reference, summarizing the current state of the art in this field. As such, it provides a valuable orientation and point of departure for current and future work in this important field of investigation. Wide dissemination should stimulate further research and study of the fundamental issues it raises.



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DEPARTMENT OF THE ARMY

US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20814-2797



19 JAN 1990

MEMORANDUM FOR Deputy Under Secretary of the Army (Operations Research),
Washington, DC 20310

SUBJECT: A Survey of Past Work on Rates of Advance in Land Combat
Operations

1. The U.S. Army Concepts Analysis Agency (CAA) is pleased to host and support our Secretary of the Army Research and Study Fellow for 1989-1990, Dr. Robert L. Helmbold, who won this Fellowship with an excellent proposal for research on rates of advance in land combat operations. This Research Paper surveys the noteworthy past work on quantitative analyses of the principal factors governing rates of advance. It is the first paper to appear under this Fellowship, and we anticipate it will be followed by others on the rate of advance data and its quantitative analysis.
2. We are not aware of any other work that covers this area as thoroughly as this Research Paper does. Thus, it provides the Army with a useful basic reference paper, summarizing the current state of the art in this field. As such, it furnishes a valuable orientation and point of departure for current and future work in this important field of investigation. Wide dissemination should stimulate further research and study of the fundamental issues it raises. Questions or inquiries should be directed to the Office of Special Assistant for Model Validation, U. S. Army Concepts Analysis Agency (CSCA-MV), 8120 Woodmont Avenue, Bethesda, MD 20814-2797, (301) 295-5228.

E. B. VANDIVER III
Director

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**A SURVEY OF PAST WORK ON RATES
OF ADVANCE IN LAND COMBAT
OPERATIONS**

**SUMMARY
CAA-RP-90-3**

THE REASON FOR PERFORMING THIS STUDY was that a short but systematic basic reference paper surveying and reviewing the current state of the art is needed to provide a sound basis for contemporary and future work on rates of advance. Unfortunately, the literature on the quantitative analysis of rates of advance is widely scattered and often hard to find. We are not aware of any other work that covers this area as thoroughly as this Research Paper does. As such, it furnishes a valuable orientation and point of departure for further work in this important field of investigation. It is hoped that wide dissemination will stimulate further research and study of the fundamental issues it raises.

THE STUDY SPONSOR was the Secretary of the Army. This is the first paper to be prepared under Dr. Robert L. Helmbold's Secretary of the Army Research and Study Fellowship, and others addressing the rate of advance data and its quantitative analysis are planned.

THE STUDY OBJECTIVE was to provide a critique and comparative survey of some of the noteworthy past quantitative analyses of the principal factors governing rates of advance in land combat operations.

THE SCOPE OF THE STUDY was intended to be comprehensive, in the sense of including all of the noteworthy work in this area. It is, no doubt, too much to hope that literally every work was indeed identified in time to be included. Nevertheless, this survey does provide an excellent overview of the current state of the art. Over 30 past works are summarized in Appendix A and reviewed in Chapter 2.

THE MAIN ASSUMPTION of this paper is that no work that would substantially alter the principal findings remains unknown.

THE BASIC APPROACHES used in this study were:

- (1) To obtain through extensive personal visits, correspondence, and phone calls all of the noteworthy quantitative analyses of rates of advance, and then to
- (2) Study, analyze, critique, and comparatively review these documents.

THE PRINCIPAL FINDINGS of this work are:

- (1) The literature is filled with controversy, reverberant with strong claims and counterclaims, few of which—despite being strongly held opinions—can muster in their support more than the weakest of evidence. There is a need for a more balanced and cool-headed view of the situation.
- (2) Past work often overgeneralizes and overextrapolates its conclusions far beyond what is reasonably supportable by its slender basis in historical fact.
- (3) Highly questionable statistical practices are often employed. Specifically, these involve blind "data-dredging," excessive overfitting, and naive application of powerful but delicately sophisticated techniques.

(4) The current state of the art suffers from inadequate appreciation for and attention to the subtle and thorny scientific, methodological, and epistemological problems and issues that must be borne in mind to achieve the best results in this field.

(5) Appreciable difficulties for future quantitative work have been created by the use of subjective/qualitative descriptors not defined in terms of objectively measurable quantities (e.g., the use of such subjective/qualitative descriptors as "intensity of enemy opposition," "degree of difficulty of the terrain," and the like).

THE STUDY EFFORT was directed by Dr. Robert L. Helmbold, Office, Special Assistant for Model Validation

COMMENTS AND SUGGESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-MV, 8120 Woodmont Avenue, Bethesda, Maryland, 20814-2797.

Tear-out copies of this synopsis are at back cover.

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STUDY SUMMARY (tear-out copies)

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A SURVEY OF PAST WORK ON RATES OF ADVANCE IN LAND COMBAT OPERATIONS

CHAPTER 1

INTRODUCTION

1-1. **BACKGROUND.** A short but systematic basic reference paper surveying and reviewing the current state of the art is needed to provide a sound basis for contemporary and future work on rates of advance. Unfortunately the current literature dealing with the quantitative analysis of historical data on rates of advance of land combat forces is widely scattered and often hard to find. We are not aware of any other work that covers this area in the depth to which this Research Paper does. As such, it affords a valuable orientation and point of departure for further work in this important field of investigation. It is hoped that wide dissemination will stimulate further research and study of the fundamental issues it raises.

1-2. **OBJECTIVE.** This paper provides a critical survey of the available quantitative analyses of the principal factors governing rates of advance in land combat operations.

1-3. **SCOPE.** The coverage of the literature was intended to be comprehensive, in the sense of including all of the noteworthy work in this area. It is, no doubt, too much to hope that literally every work actually identified in time to be included. Nevertheless, this survey should provide an excellent overview of the current state of the art. Over 30 past works are summarized in Appendix A and reviewed in Chapter 2.

1-4. **ASSUMPTIONS.** The main assumption of this paper is that no work that would substantially alter its principal findings remains unknown.

1-5. **APPROACH.**

a. The basic approach used in this study was to obtain through extensive personal visits, correspondence, and phone calls all of the noteworthy documents on the quantitative analysis of rates of advance. A thorough search of the Defense Technical Information Center (DTIC) holdings was made for works keyed to such terms as advance, movement, Army operations, mobility, maneuver and so forth. Each work whose abstract, date of publication, and point of origin indicated relevance to this paper's objective were obtained. In addition, inputs were solicited through advertisements in PHALANX (the military operations research newsletter), on the FORUM computer bulletin-board system (using both its Army-wide FORUMNET and the special military history HISTORYNET), the Army ORSA bulletin-board system, and personal contact with some 50-odd US and foreign government organizations, industrial firms, and educational institutions. These included (but were not limited to) such agencies as the Institute for Defense Analyses, the Center for Naval Analyses, The RAND Corporation, the Brookings Institution, the US Army Center of Military History, TRADOC Headquarters, TRAC, US Army Command and General Staff College, US Army War College, Air Force Center for Studies and Analyses, the various National Laboratories, the major operational research establishments of SHAPE, the United Kingdom, Canada, and the Federal Republic of Germany, and the principal US military study and analysis contractors such as SAIC, PRC, SPC, etc., as well as many others. In each case, we asked them not only to furnish or suggest whatever relevant materials they themselves had, but also to direct us to any other points of contact they thought might be fruitful, and all such leads were followed up. Appendix C provides a

bibliography of the works collected and consulted.

b. Having secured the relevant documents, we then proceeded to study, analyze, critique, and comparatively review them.

1-6. FINDINGS. The principal findings of this work are:

a. The literature is filled with controversy, reverberant with strong claims and counterclaims, many of which—despite being strongly held opinions—can muster in their support only the weakest of evidence. There is a need for a more balanced and cool-headed view of the situation.

b. Past work often overgeneralizes and overextrapolates its conclusions far beyond what is reasonably supportable by its slender basis in historical fact.

c. Highly questionable statistical practices are often employed. Specifically these involve blind "data-dredging," overfitting of data, and naive application of powerful but delicately sophisticated techniques.

d. The current state of the art suffers from inadequate appreciation of and attention to the subtle and thorny scientific, methodological, and epistemological problems and issues that must be borne in mind to achieve the best results in this field.

e. Appreciable difficulties for future quantitative work have been created by the use of subjective/qualitative descriptors not defined in terms of objectively measurable quantities (e.g., the use of such subjective/qualitative descriptors as "intensity of enemy opposition," "degree of difficulty of the terrain," and the like).

1-7. OTHER OBSERVATIONS.

a. The field is plagued by a confusing babel of *ad hoc* terminology, haphazard choices of what descriptors to report or omit, and arbitrary ways of describing environmental and operational factors.

b. Some past work doesn't describe clearly just what statistical methods were used. Sometimes past work blurs the distinction between the numerical results of statistical computations and the author's interpretation of them.

c. Few works attempt to compare directly the rates of advance forecast using either an entire wargame or just its movement subroutine to those in an actual combat situation. This could be a fertile field for future investigations.

d. Since formal model selection criteria can help strike a judicious balance between the importance of a parsimonious representation of the data and the desirability of a good fit, they may help to reduce the tendency toward overfitting. One such criterion is Akaike's Information Criterion (see among others: Sakamoto, Y., M. Ishiguro, G. Kitagawa, "Akaike Information Criterion Statistics," Reidel, D., Dordrecht, Holland, 1986; Linhart, E. and W. Zucchini, "Model Selection," John Wiley, NY, 1986; Akaike, H., "Information Theory and an Extension of the Maximum Likelihood Principle," in Proceedings of the Second International Symposium on Information Theory, eds. B. Petrov and F. Czaki, Budapest: Akademiai Kiado, pp. 267-281.)

e. More-or-less blind multivariate analysis, data analysis, sophisticated statistical methods, and so forth haven't been very successful at pinpointing the causes of advances and withdrawals in land combat operations. The reasons for this are not very clear. However, those who would propose to use such methods need to consider past experiences and should seek to improve upon them.

CHAPTER 2

COMPARATIVE ANALYSIS

2-1. **INTRODUCTION.** This chapter presents a few comparative analyses of past work on rates of advance in land combat operations. Other comparisons could be drawn, but those included suffice to illustrate and to support the main findings of this paper. References to specific summaries are by their short names, e.g., CLAUSEWITZ-1832 refers to the summary of the same short name in Appendix A.

2-2. **ENVIRONMENTAL DESCRIPTORS.** Most past studies use rather brief descriptors to indicate the tactical situation's environmental and operational conditions. There is no one descriptor used in each of the past studies summarized in Appendix A. Nor is there one study that uses all of them. To illustrate these points, this paragraph focuses on just the environmental descriptors, and indeed within them on just the terrain descriptors. Selected operational descriptors are considered in paragraph 2-3.

a. Most of the terrain descriptors merely indicate the general sort of terrain and do not actually define it in an objectively-measurable way. We found two exceptions (or perhaps three, depending on one's point of view), which are cited below. Notice that since they do not use the same categories, the differences go beyond the merely terminological. Nor are the categories exhaustive as well as mutually exclusive. For example, where does terrain with elevation changes of 100 to 300 meters per mile fit in Parsons' categories? Where does heavily wooded flat or rolling terrain fit in de Santis' categories?

(1) PARSONS-1954 uses the terrain descriptors *open*, *moderately open*, *moderately close*, *close*, and *mountainous*, defined as follows:

(a) Open (lightly wooded, slightly rolling, elevation changes less than 30 meters per mile and not more than 25 percent woods cover)

(b) Moderately open (wooded and rolling, elevation changes 30 to 50 meters per mile or 25 to 50 percent woods cover)

(c) Moderately close (wooded and hilly, elevation changes 80 to 100 meters per mile or 50 to 75 percent woods cover)

(d) Mountainous (elevation changes over 300 meters per mile).

(2) DESANTIS-1972 uses the terrain descriptors *open*, *median*, and *close*, defined as follows:

(a) Open terrain is flat or slightly rolling, with little vegetation, and has a contour interval variation from 0 to 100 meters per kilometer, permitting maximum cross-country movement;

(b) Median terrain is rolling terrain, lightly covered with trees and other vegetation with a contour interval variation of 100 to 200 meters per kilometer produced by small hills with gentle slopes causing a slight reduction of cross-country movement;

(c) Close terrain is rough, heavily wooded terrain with a contour interval variation of 200 to 400 meters per kilometer or more. This variation is considered sufficient to cause significant slowing of cross-country movement.

(3) WAINSTEIN-1973A uses the descriptors *open*, *mized*, *difficult*, and provides the following discussion without actually defining them: "Terrain has been

categorized as (1) open, (2) mixed, and (3) close or difficult. The word mixed thus includes the two commonly used descriptors, moderately open and moderately close, the distinction between which is really rather fine and essentially judgmental. ... it is generally not possible to distinguish what proportion of an action occurred in a town versus the proportion that occurred on the open ground around it."

b. Some examples of the terrain descriptors used by these and other studies are listed in Table 2-1. An entry of NR means that terrain is not relevant to the study's main purpose, and hence no comment is appropriate.

2-3. STRENGTH DESCRIPTORS. Many operational descriptors are possible, and the studies use a variety of them. However, in this paragraph we focus on just the descriptors of attacker and defender strengths. Table 2-2 lists them, where again NR means that strength descriptions are not relevant to the study. Some studies used several measures of strength (e.g., firepower potentials, etc.) and all of the one's used are included. The entry "unit designation" means that the general size of the unit is indicated by its level in the usual hierarchy, i.e., battalion, regiment, etc. "Strength" refers to personnel strength. All allusions to "resistance" refer to characterizations of the defender's resistance. The entry QJM is an abbreviation for Quantified Judgment Model (see, e.g., Trevor N. Dupuy, "Numbers, Predictions & War," The Bobbs-Merrill Co., Indianapolis, 1979).

2-4. SUSPECTED ATTACKER BIAS

a. The following explains what we mean by attacker bias. Some studies select cases for examination based on whether or not the attacker actually succeeded in advancing. When the intent is to study unopposed advances, this may be entirely acceptable. However, some studies of opposed advances *also* use such selection practices. Perhaps they reasoned that "If we are going to study rates of advance, hadn't we better study cases in which there *was* an advance?" Unfortunately, of course, such reasoning is specious and the resulting selection process merely biases the sample. Ideally, all attempted advances would be included and we would see just how much ground they gained or lost. This would certainly result in there being no biases whatever, but this counsel of perfection is seldom attainable. In practice there is almost sure to be some biases, so the practical issue is to gain at least an "appreciation" for the effects of whatever biases there are. Those effects can range from quite negligible to utterly disastrous, so its too bad that the studies under review don't even mention these selectivity and bias issues, much less discuss their impact on study findings. Perhaps these issues escaped their notice. When there is a selection bias toward attacks that actually succeeded in advancing, and it is sizable enough to have a serious impact on study findings, we say that the study suffers from attacker bias.

b. In some studies, the attacker bias obviously is present and clearly is sizable enough to impact on study findings. More often the attacker bias is so subtle that assessing its impact is hard. Some studies provide too little information to weigh its impact. Despite these problems I somewhat rashly offer in Table 2-3, for whatever they may be worth, my tentative judgments of the seriousness of the attacker bias. In this table an entry of Y indicates that I think the attacker's bias is serious enough to impact study findings and feel pretty sure of that judgment; an entry of Y? indicates that I feel the attacker bias is serious but am not so sure of that judgment; an entry of ?? indicates that the matter is so complex or the information so scanty that I decline to hazard a guess; an entry of N? indicates that I don't think the attacker bias is serious but am not so sure of that judgment; and an entry of N indicates that I don't think the attacker bias is serious and feel pretty sure of that judgment. An entry of NR indicates that attacker bias is not relevant and is used for all studies dealing only with unopposed advances, as well as for a few others where study findings are presented in a way that

Table 2-1. Examples of Terrain Descriptors Used

Study name	Terrain descriptors used
VEGETIUS-380	flat, mountains
CLAUSEWITZ-1832	flat, mountains
BAORG-1952	open, close (close = wooded or built-up)
RAND-1953	none used
HULSE-1954	moderately open, close, mountainous
PARSONS-1954	open, moderately open, moderately close, mountainous
ANDREWS-1960	desert, mountainous, neither
BEKKER-1962	NR (at least for the part summarized in Appendix A)
BEST-1966	none used
OVERHOLT-1970	claims terrain used, but how is not indicated
MADER-1971	NR
MEFORD-1971	none used
PEARSALL-1972	flat, rolling, rugged
DESANTIS-1972	open, median, close
ORALFORE-1972	roadnet mobility characterized as: unlimited cross-country movement, good road net, fair road net, poor road net, impassable terrain. Exceptional obstacles characterized as: river, flooded area, fortified zone, exceptionally effective demolitions, urban area, sabotage by local populace, desert
RECORD-1973	Europe, desert
WAINSTEIN-1973a	open, mixed, close or difficult
WAINSTEIN-1973b	NR
BARRIER-1974	obstacles described in some detail in narrative accounts of the action; shorthand descriptor terms not used
RMC-1974	no significant limitation on tank or infantry movement, tank movement canalized but infantry movement unaffected, tank movement severely canalized but infantry movement unaffected, tanks must breach an obstacle to advance but infantry movement not significantly limited, both tank and infantry movement canalized, infantry movement canalized and tank movement severely canalized, tanks must breach an obstacle to advance and infantry movement canalized, tanks must breach a difficult obstacle to advance and infantry movement canalized, both infantry and tanks must breach an obstacle to advance (e.g., a river), both infantry and tanks must breach a difficult obstacle to advance
FEBA-1975	all six combinations of [flat, rolling, rugged] with [bare, mixed]
MURPHY-1975	NR
QUICK WINS-1975	none used
LINDLEY-1976	NR
BREAKTHRU-1976	great advantage, advantage, disadvantage, great disadvantage
SCHÄFFER-1977	same as RMC-1974
FALLACY-1977	NR
IABG-1978	NR
DUPUY-1982	difficult terrain, rivers and canals, quality and density of roads
SIMPKIN-1984	good and bad roads
WAINSTEIN-1984	described in accompanying discussion; descriptors not used
ANTHONY-1987	NR
DUPUY-1987	NR
ROWLAND-1989	mean ridge height

Table 2-2. Examples of Strength Descriptors Used

Study name	Strength descriptors used
VEGETIUS-380	NR
CLAUSEWITZ-1832	divisions for attacker; defender NR
BAORG-1952	number of attacking companies; defender strengths not used
RAND-1953	number of equivalent divisions on line for each side
HULSE-1954	unit designation for attacker; very light, moderate, heavy for resistance
PARSONS-1954	unit designation for attacker; none, light, heavy for resistance
ANDREWS-1960	NR
BEKKER-1962	NR
BEST-1966	NR
OVERHOLT-1970	personnel strength for attacker and defender
MADER-1971	NR
MEFORD-1971	personnel strength, firepower potential, QJM lethality for each side
PEARSALL-1972	strength, QJM lethality for each side
DESANTIS-1972	JIFFY wargame combat power index for each side
ORALFORE-1972	strength, QJM lethality for each side
RECORD-1973	NR
WAINSTEIN-1973a	strength for attacker; light, moderate, heavy for resistance
WAINSTEIN-1973b	NR
BARRIER-1974	NR
RMC-1974	infantry platoon equivalents for each side
FEBA-1975	strength for each side
MURPHY-1975	NR
QUICK WINS-1975	none used
LINDLEY-1976	same as RMC-1974
BREAKTHRU-1976	strength, firepower potential, QJM combat power, QJM effective combat power for each side
SCHÄFFER-1977	same as RMC-1974
FALLACY-1977	NR
IABG-1978	NR
DUPUY-1982	force ratio, combat power preponderance, combat effectiveness superiority
SIMPKIN-1984	NR (at least for the part summarized in Appendix A)
WAINSTEIN-1984	unit designation for attacker; none for defender
ANTHONY-1987	NR
DUPUY-1987	strength
ROWLAND-1989	NR

Table 2-3. Examples of Suspected Attacker Bias

Study name	Author's judgmental assessment
VEGETIUS-380	NR
CLAUSEWITZ-1832	NR
BAORG-1952	Y?
RAND-1953	Y?
HULSE-1954	Y
PARSONS-1954	Y
ANDREWS-1960	NR
BEKKER-1962	NR
BEST-1966	NR
OVERHOLT-1970	N
MADER-1971	NR
MEFORD-1971	N?
PEARSALL-1972	N?
DESANTIS-1972	Y?
ORALFORE-1972	Y
RECORD-1973	NR
WAINSTEIN-1973a	Y
WAINSTEIN-1973b	NR
BARRIER-1974	N
RMC-1974	??
FEBA-1975	N?
MURPHY-1975	NR
QUICK WINS-1975	NR
LINDLEY-1976	NR
BREAKTHRU-1976	NR
SCHÄFFER-1977	??
FALLACY-1977	N?
IABG-1978	NR
DUPUY-1982	N
SIMPKIN-1984	NR (at least for the part summarized in Appendix A)
WAINSTEIN-1984	Y
ANTHONY-1987	NR
DUPUY-1987	N?
ROWLAND-1989	NR

isn't affected by attacker bias. It should be plainly understood that these judgments are tentative and reflect only my current opinions. They may be changed at any time.

c. Of course several other types of bias are possible. For example, there could be a defender bias (i.e., a deliberate or unwitting tendency to select actions that had a successful defense), a bias against meeting engagements, and so forth. They are not explored here because so few studies give enough information to judge either their presence or impact. However, this should not be interpreted as suggesting that the studies do not exhibit these biases, or that they are not important.

2-5. WHAT GOVERNS RATES OF ADVANCE? The studies are not of one mind on this important question. The following list gives a condensation of each study's position on it. The only point to be made here is that there is no consensus. To keep the presentation short, I have drastically simplified and abbreviated the study's position. I consider this loss of fidelity to the originals acceptable, since my sole aim is to illustrate the *range and variety* of viewpoints and *not* to detail any one study's particular perspective. The studies that inspired these condensations are given, but those who in the spirit of this paragraph are interested only in the range of views should ignore the sources and focus on the condensations. Besides illustrating the contradictory findings of past studies, these condensations and the summaries in Appendix A are good sources of hypotheses. As usual, NR means not relevant. ROA is an abbreviation for "rate(s) of advance." The phrase "defender posture" is synonymous with defender mission (e.g., defend in place, conduct a withdrawal, etc.). When the defender's state of physical protection is intended, we refer to the defender's fortifications.

- a. VEGETIUS-380. Physical fitness makes for high ROA.
- b. CLAUSEWITZ-1832. There is a sustainable rate of march. It can be exceeded for a time but if pressed too hard will seriously damage the force.
- c. BAORG-1957. ROA varies inversely with the intensity of opposition, size of the force, distance to the objective, night (*vs* day), and ruggedness of terrain.
- d. RAND-1953. ROA varies directly with force ratio, but there may be a threshold force ratio below which advances are not possible.
- e. HULSE-1954. Force ratios and terrain determine ROA.
- f. PARSONS-1954. Force ratios and terrain determine ROA.
- g. ANDREWS-1960. Unopposed advance rates decline if marches are sufficiently prolonged.
- h. BEKKER-1962. There are some very fundamental physical or technological limits to how fast vehicles can go.
- i. BEST-1966. While, statistically speaking, ROA varies inversely with casualty rate, it is doubtful that either causes the other. Instead, conditions favoring high ROA also tend to favor low casualty rates, and *vice versa*.
- j. OVERHOLT-1970. Casualties determine ROA. Force ratios have little to do with ROA.
- k. MADER-1971. NR
- l. MEFORD-1971. ROA are not determined by force ratios.
- m. PEARSALL-1972. ROA depends on the defender's *posture*, and not on terrain or anything else.

- n. DESANTIS-1972. ROA depends on the ratio of (the JIFFY wargame variety of) relative combat power indices, which in turn depend in a complicated way on the size and composition of the opposing forces, on the local terrain, and on the attacker's tactics. (But not on the weather or on day/night conditions.)
- o. ORALFORE-1972. RCA varies inversely with casualty rates of the attacker and the presence of major obstacles. There may be a force ratio threshold below which advances are not possible. ROA also depends on the missions of the opposing forces, and perhaps on several other considerations.
- p. RECORD-1973. Rates of advance actually achieved by large forces are far below those of their principal modes of transportation. This betokens some fundamental limitations in how fast large forces can advance, which will govern ROA no matter what the doctrine and field regulations prescribe.
- q. WAINSTEIN-1973a. Defensive posture and terrain difficulties tend to go hand in hand. (It may be that this reflects a tendency for the defender to select difficult terrain as the place to make his most determined stands.)
- r. WAINSTEIN-1973b. Some of the most widely-used figures on rates of advance may have little basis in historical fact.
- s. BARRIER-1974. ROA is not related to force ratio.
- t. RMC-1974. ROA depends on force ratio, but it is only one of 25 terms in the equation. Increases in any of these factors will eventually exhibit diminishing returns, if the others are held fixed.
- u. FEBA-1975. ROA depends significantly on force ratio. Defense posture is also significant, but weather, season of year, and terrain are not.
- v. MURPHY-1975. Its not possible to determine *what* factors affect ROA.
- w. QUICK WINS-1975. A preponderance of effective force strength matters, but can to some extent be mitigated by clever tactics.
- x. LINDLEY-1976. Defensive posture, relative strengths, national character, and counterattacks seem to affect ROA. But all of these taken together influence ROA no more than other unknown and perhaps purely random factors.
- y. BREAKTHRU-1976. ROA are unrelated to force ratios.
- z. SCHÄFFER-1977. Force ratios are important, but only one of some 17 terms in the equation.
- aa. FALLACY-1977. ROA are unrelated to force ratios.
- ab. IABG-1978. ROA depends directly upon force ratios, and there is a threshold below which sustained advances are not possible. ROA also vary inversely with the attacker's losses. Five operational and four environmental factors also affect ROA.
- ac. DUPUY-1982. Advances require combat power preponderance. But force ratios don't affect ROA. Yet combat effectiveness superiority enhances ROA. ROA varies directly (as opposed to inverse) with casualties, since all-out efforts increase ROA at the expense of casualties. ROA varies inversely with terrain difficulty, presence of rivers and canals, scarcity of good roads, bad weather, defender fortifications, nightfall, and duration of the operation.
- ad. SIMPKIN-1984. For at least one class of operational movements, it's hard to see any dependence of ROA on day/night, good/bad roads, dry/wet weather, or number of routes used.

ae. WAINSTEIN-1984. ROA depends on many things, but enemy resistance, well fortified and defended positions, obstacles (especially enemy emplaced), congestion, and logistic constraints seem to be rather consistently mentioned in unit records or histories.

af. ANTHONY-1987. ROA may be fractal (or chaotic). If so, traditional methods of data analysis may not work very well.

ag. DUPUY-1987. ROA does not depend of force ratios.

ah. ROWLAND-1989. Unopposed ROA are higher for mechanized forces than for nonmechanized.

APPENDIX A

SUMMARIES OF KEY WORKS ON RATES OF ADVANCE

A-1. PURPOSE AND SCOPE. This appendix summarizes and comments on several key works on rates of advance in land combat. The intent was to be comprehensive, i.e., to include all noteworthy works of this nature. Surely we cannot hope to have been entirely successful. Nevertheless, over 30 key works are summarized in the appendix, and this coverage gives us a reasonable expectation that any works as yet unknown or unavailable to us would not substantially alter this paper's principal findings. The principal criteria for inclusion are that the work assert important and definite quantitative generalizations about rates of advance of land combat forces, and that it base them explicitly upon a quantitative analysis of some body of historical data. Although these criteria have not been applied overly strictly, they serve to exclude those wargaming handbooks and similar literature that make assertions about rates of advance without presenting any substantial or specific supporting evidence. We have very particularly in mind assertions accompanied only by vague allusions to their being "based on historical data," when no specific historical data are cited or in evidence.

A-2. MANNER OF PRESENTATION. The summaries and commentaries are presented in chronological order of their appearance. Each summary starts on a separate page, and for reference purposes is given a short title (usually the author's last name in capitals and the date the work appeared, i.e., CLAUSEWITZ-1832). The first paragraph of the summary gives identifying information such as the title, author, etc. The second paragraph describes the document's purpose and scope. This is followed by a series of paragraphs recounting the sources cited by the document, outlining how it defines the distances and times of advance, and describing how it characterizes tactical situations. This is followed by a summary of the document's main conclusions regarding rates of advance. At the end we provide our own overall commentary and critique of the document's sources/data, methods, and results. [Our paraphrases and interpolations are enclosed in square brackets, like this, to distinguish them from the original.]

A-3. SOME BURNING QUESTIONS. The interested reader may wish to keep in mind the following important issues while reviewing the summaries, and to consider how well past work responds to them:

- a. What starts a force in motion?
- b. Once started, what governs the force's speed and direction?
- c. What eventually arrests or reverses the force's direction?
- d. Where and when does the force stop or reverse direction?
- e. How is distance determined? Do all the documents surveyed define it consistently?
 - (1) Initial to final position of some vehicle, or unit?
 - (a) Straight-line distance?
 - (b) Along axis of main advance?
 - (c) Odometer distance?
 - (d) Following the actual route of some element?
 - (e) Initial to final location?
 - (f) Only forward of the original Forward Edge of the Battlefield (FEBA) trace?

- (2) FEBA trace to FEBA trace?
 - (a) Maximum displacement?
 - (b) Average displacement?
 1. Which sector of the front applies to this average?
 2. What time applies to this average?
- f. How is time interval determined? Do all the documents surveyed define it consistently?
 - (1) Start-to-finish (door-to-door)?
 - (2) Only time spent "in motion"?
 - (3) Only time spent moving toward goal?
- g. What do such situational descriptors as the following really mean? How could they be defined more precisely and objectively? Do all the documents surveyed define them consistently?
 - (1) Flat, hilly, rugged, mountainous, level.
 - (2) Open, medium, close terrain.
 - (3) Wooded, urban, brushy.
 - (4) Wet, rainy, snow-covered, muddy, stormy.
- h. Is there a bias toward the attacker, or are unsuccessful attacks and attacks that wound up losing ground to enemy counterattacks treated on an equal footing with attacks that were either fully successful (in the sense that they seized their intended terrain objectives) or partly successful (in the sense that at least a modest advance was achieved, whether the intended terrain objective was taken or not)? Are the documents surveyed consistent with regard to possible attacker biases?

A-4. CROSS-REFERENCE LISTING. It is sometimes convenient to have a cross-reference listing the documents surveyed alphabetically by their short name rather than by date. The following provides such a cross-reference listing for the convenience of the reader.

<u>Number</u>	<u>Short name</u>
1	ANDREWS-1960
2	ANTHONY-1987
3	BAORG-1952
4	BARRIER-1974
5	BEKKER-1962
6	BEST-1966
7	BREAKTHRU-1976
8	CLAUSEWITZ-1832
9	DESANTIS-1972
10	DUPUY-1982
11	DUPUY-1987
12	FALLACY-1977
13	FEBA-1975
14	HULSE-1954
15	IABG-1978
16	LINDLEY-1976
17	MADER-1971
18	MEFORD-1971
19	MURPHY-1975
20	ORALFORE-1972

21	OVERHOLT-1970
22	PARSONS-1954
23	PEARSALL-1972
24	QUICK WINS-1975
25	RAND-1953
26	RECORD-1973
27	RMC-1974
28	ROWLAND-1989
29	SCHÄFFER-1977
30	SIMPKIN-1984
31	VEGETIUS-380
32	WAINSTEIN-1973a
33	WAINSTEIN-1973b
34	WAINSTEIN-1984

A-5. CONVERSION FACTORS. The original reports reviewed use a variety of units. Some handy conversion factors are (see, for example, Mechtley, E. A., "The International System of Units: Physical Constants and Conversion Factors," NASA SP-7012, Second Revision, Scientific and Technical Information Office, National Aeronautics and Space Administration, Washington, DC, 1973):

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
miles/day	1.609344	km/day
kiloyard/day	0.9144	km/day
yards/hour	$0.9144 \times 24 / 1000$	km/day

VEGETIUS-380

1. Document:

- a. Title: Military Institutions of the Romans
- b. Author: Flavius Vegetius Renatus (Vegetius)
- c. Date: Circa 380 AD
- d. Organization: Stackpole Books, Harrisburg, PA 1944 (reprinted by The Telegraph Press, Harrisburg, PA, July 1965)
- e. Number: NA

2. Objectives and Scope:

a. Vegetius' book can be interpreted as bemoaning a decline from the manly virtues of the hardy Romans of the old Empire, and a call to reverse the growing softness and flabbiness among his contemporaries.

b. We consider only the portions of Vegetius' work that deal with the training marches and regimens of the Romans.

3. Using the Following Data Sources: Unspecified

4. Distance Defined As: Unspecified

5. Time Interval Defined As: Unspecified

6. Situational Descriptors Defined As: Training marches and regimen

7. Summary of Conclusions Regarding Advances: Vegetius (*passim*) states that "It was a common custom among the old Romans ... to exercise both cavalry and infantry three times a month by marches of a certain length. The foot were obliged to march completely armed a distance ten miles from the camp and return, in the most exact order and with the military step which they changed and quickened on some part of the march. ... They made these marches not only on even ground, but both cavalry and infantry were ordered into difficult and broken terrain and to ascend or descend mountains ... They should march with the common military step twenty miles in five summer hours [about half a summer's day], and with the full step, which is quicker, twenty-four miles in the same number of hours. If they exceed this pace they can no longer march but run ... Recruits in particular should be obliged frequently to carry a weight of not less than sixty pounds (exclusive of their arms), and to march with it in the ranks."

8. Comments and Critique:

a. This work is cited as an interesting baseline and point of departure for the presentation of more recent works on rates of advance.

b. Dodge (Dodge, Theodore Ayrault, "Alexander: A History of the Origin and Growth of the Art of War from the Earliest Times to the Battle of Ipsus, BC 301, With a Detailed Account of the Campaigns of the Great Macedonian," Houghton, Mifflin and Co. Boston and New York, 1898 (2nd Ed.). First Edition, 1890) claims that the Macedonians (circa the time of Alexander the Great) made similar training marches of 30 miles a day.

CLAUSEWITZ-1832

1. Document:

- a. Title: On War
- b. Author: Clausewitz. Carl von
- c. Date: 1832
- d. Organization: Prussian Military
- e. Number: Translation by Michael Howard and Peter Paret, Princeton University Press, Princeton, NJ, 1976

2. Objectives and Scope:

a. Clausewitz desires to illustrate by example the mechanics of marches, whereby forces can be brought from one position to another.

b. The examples he uses to illustrate his main points.

3. Using the Following Data Sources: Unspecified

4. Distance Defined As: Unspecified

5. Time Interval Defined As: Unspecified

6. Situational Descriptors Defined As: Unspecified

7. Summary of Conclusions Regarding Advances:

a. (pg 316) "Experience also teaches that the head of a column of four divisions with a cavalry reserve can generally do fifteen miles in eight hours, even on inferior roads. At the rate of an hour per division, and the same for the cavalry and artillery reserves, the march will take thirteen hours to complete. This is not too long a time, and yet enough for a total of 40,000 men to march along one road."

b. (pg 319) "Modern armies have long been accustomed to consider a fifteen-mile march as a day's work. In extensive operations, it must be reduced to an average of ten miles in order to allow for the requisite days of rest on which necessary repairs and maintenance can be carried out.

"A division of 8,000 men takes eight to ten hours for such a march in level country and on ordinary roads. In mountainous country, it will take ten to twelve [hours]. If a column consists of a number of divisions, a few hours longer will be required, even discounting the delayed starting time of the later divisions.

"It is clear that the day is pretty well filled by such a march, and that one cannot compare the strain on a soldier loaded with his pack for ten or twelve hours with an ordinary fifteen-mile walk which would not take an individual more than five hours on a decent road.

"Forced marches, if undertaken one at a time, may cover twenty-five miles, or thirty at the most; if they continue, only twenty.

"A march of twenty-five miles will call for a rest stop of several hours, and a division of 8,000 men will not manage it in less than sixteen hours even on good roads. If the distance to be covered is thirty miles and several divisions are involved, one has to allow a minimum of twenty hours."

c. (pp 320-321, *passim*) "[The] Prussian army, on its retreat in 1806, [had it done some things differently] need not have made immense exertions to cover some 250 miles in no less than fourteen days. $[250/14 = 17.86 \text{ mi/day} = 28.74 \text{ km/day}]$... So the Seven Year's War produced marches that have still not been surpassed: Lascy's, for

instance, in 1760, in support of the Russian diversion toward Berlin. He covered the 220 miles from Schweidnitz through Lusatia to Berlin in ten days—a rate of 22 miles a day, which would be astounding even nowadays for a corps of 15,000 men. [22 mi/day = 35.41 km/day] ... Hence the fact that Bonaparte, when pursuing the Prussians and trying to cut off their retreat in 1806, and Blücher, intending to do the same to the French in 1813, both required ten days to cover only 150 miles or so. That was a rate which Frederick the Great achieved, baggage and all, when marching from Saxony to Silesia and back. ... In general, the reduction in baggage will result in a saving of effort rather than an acceleration of movement."

d. (pp 322-324, *passim*) "A single moderate march will not blunt the instrument [i.e., the fighting forces]; but a series of moderate marches will begin to tell, while a series of strenuous marches will naturally do much greater harm. ... A march of 500 miles or more will always cause an army to arrive at its destination in a highly weakened condition, especially where horses and wagons are concerned. ... Bonaparte's advance was indeed unrelenting, from the crossing of the Niemen up to Moscow; but one must bear in mind that it took 82 days to cover only about 600 miles, and that the army stopped altogether—once for some 14 days at Vilna and the other time for some 11 days at Vitebsk—which must have given many stragglers time to catch up. ... Great wear and tear on one's own forces, therefore, must be expected if one intends to wage a mobile war. All other plans must be adjusted to that fact; and above all, replacements must be provided for."

e. (pg 545) "Naturally we assume that the defender will act as sensibly and correctly as the attacker. We say this in order to exclude certain vague notions about sudden assaults and surprise attacks, which are commonly thought of as bountiful sources of victory. They will only be that under exceptional circumstances."

8. Comments and Critique:

a. Clausewitz's cautions should be borne in mind in interpreting advance rate numbers from whatever sources.

b. It is interesting to note that rates of march did not change much between the times of Vegetius and Clausewitz. This suggests some fundamental limitations in moving large bodies of troops, not readily overcome by changes in technology or technique. Clausewitz's examples also provide information on the planning factors and experiences in moving large bodies of troops in his time.

BAORG-1952

1. Document:

- a. Title: An Analysis of Infantry Rates of Advance in Battle
- b. Author: Gould, A. H., and H. Gee
- c. Date: November 1952
- d. Organization: British Army Operational Research Group
- e. Number: Report No. 17/52

2. Objectives and Scope:

a. The aim was to determine the feasibility of quoting a figure representative of the average rate of infantry advance, at the same time assessing the influence of a number of operational variables on (1) the rate of advance and (2) the associated casualties per company.

b. Some 351 rates of advance are tabulated and analyzed. The actions took place in Northwest Europe during January-March 1945 (167 actions) or in Italy during January, June, July, or October 1944 (164 actions). All of the actions studied were operations of British infantry battalions, generally supported by tanks and artillery, employing from one to four companies of infantry. The actions break down as follows:

<u>No. of infantry cos involved</u>		<u>No. of actions</u>
	1	56
	2	74
	3	194
	4	1
Total	NA	331

3. Using the Following Data Sources: The data were extracted from about 110 British infantry Battalion War Diaries.

4. Distance Defined As: (pg 1) "Distance in yards covered by infantry on foot in the advance from start line to objective."

5. Time Interval Defined As: (pg 1) "Time taken from crossing the start line to the leading troops reaching the objective."

6. Situational Descriptors Defined as: (from pg 1 unless otherwise noted)

- a. "Strength of our own troops in terms of numbers of companies in attack."
- b. "Type of country typified by the Theatres of War, i.e., Northwest Europe or Italy, these being representative of relatively flat and mountainous going respectively." The data tabulations also indicate the general area involved (e.g., Holland, Reichwald Area, Cleve, etc.).
- c. "Within each area [i.e., Theatre of War], [type of terrain] by the local nature of the country, defined as open, close (i.e., wooded) or built-up."
- d. "Advance by day or night."
- e. "Number of casualties suffered by own troops."

f. (pg 3) "Although in many actions some statement of the fire support was made, in general the description lacked precision, such statements as "RA" [Royal Artillery] or "Tanks" being the sole description. It was considered impractical to give measure to such general statements and consequently this factor has not been incorporated into the analysis." However, the data tabulations note when such statements were provided in the War Diaries.

g. (pg 3) "Similarly the strength of enemy opposition has been classified under only two headings, heavy and slight, again without allowance being made for the variations within these headings. No detail was available as to the support arms used by the enemy."

7. Summary of Conclusions Regarding Advances (from pp. 4-8 unless otherwise noted):

a. "The rate of advance against heavy opposition was very much less than against slight. There was a marked decrease in the rate of advance as more companies were involved. The rate of advance in Italy was very much less than that in NW Europe. The rate of advance by day was noticeably greater than by night. The rate of advance achieved in the longer advances was appreciably greater than in the shorter advances."

b. "The most influential factors affecting the rate of advance appeared to be the strength of enemy opposition and the distance advanced. As far as the latter is concerned this is considered to be due to the fact that in many of the long advances an appreciable proportion of the time may be spent in advancing without appreciable conflict, whilst the shorter advances are representative of set piece attacks under conditions of strenuous opposition."

c. "Both the strength of attack and the theatre of war exert a marked influence on the rate of advance. The difference in the rates of advance experienced in Italy and NW Europe is not surprising. In addition to the comparatively mountainous nature of the terrain, the quality of enemy opposition experienced in Italy was such as to be likely to reduce the rate of advance in that theatre. It is, however, important to appreciate that although the analysis has shown this factor to be important the extent of the difference is only of the order of 30%."

d. "The day/night difference is one which on general grounds was to be expected. The magnitude of the effect (day rate 26% greater than night rate of advance) is not as great as at first appeared. This is because the advances by day include a far greater proportion of long advances, which as has already been shown, are at a greater average rate of advance."

e. "It is also noteworthy that the analysis shows no pronounced difference between the rates for open and closed country."

f. "Since the rate of advance and the casualties per company suffered have been expressed in terms of the same factors, it is theoretically possible to relate these two elements. On this basis the following mathematical formula was obtained:

$$V = [kd/(1 + c)]^{1/4}$$

where V is the rate of advance (yards per hour), k is a constant, d is the distance between start line and objective (yards), and c the casualties per company.

"It must be stressed that this formula is deduced solely from the relationships obtained between the rate of advance, the casualties sustained and the other factors in terms of the statistical analysis carried out. There is no fundamental mathematical theory which leads to the assumption of this formula. The constant k depends on the

specific combination of the other factors known to exist, i.e., theatre of war, day or night, strength of enemy opposition and the strength of attack.

"It will be seen that according to this formula, as the rate of advance increases, so the number of casualties decreases. This does not imply that under any given set of conditions which govern an action, the number of casualties can be reduced by increasing the rate of advance. The interpretation of this formula is simply that under those conditions in which it is possible to achieve a higher rate of advance, equally the number of casualties sustained is low."

g. "The following factors were found to have a significant influence on rates of advance:

- (1) The topographical characteristics of the theatre of war
- (2) Day or night advance
- (3) Strength of the attack
- (4) Strength of enemy opposition

"The estimated rate of attack varies according to the conditions of the above factors, the least estimate being 235 yards per hour for a battalion [sized] attack at night in Italy against heavy opposition [conducted as] a set piece attack at 800 yards [distance to the objective], as compared with approximately 1,290 yards an hour for a one-company [sized] attack by day in NW Europe against light opposition [at] 2,500 yards [distance to the objective]."

8. Comments and Critique:

a. This is an excellent study, clearly and concisely reported. The data seem to be exceptionally carefully compiled. It appears to be the earliest study that attempts in a systematic way to assess quantitatively the influence of various factors upon rates of advance in land combat, or to employ modern statistical techniques to analyze the data.

b. (pg 3) "It was not possible, of course, to estimate to what degree the rates of advance which were studied were conditioned by previous planning. This element would be particularly important in timed operations employing two or three companies."

c. (pg 3) "Whilst it is reasonable to assume that [the prevailing weather conditions] may materially affect the course of the action, this factor had to be neglected as, in the majority of instances, no precise statement of weather conditions was available."

d. (pg 3) "[Training and battle experience of the troops], which applies not only to our forces but also to the enemy forces opposing the advance, is again neglected for reasons similar to those stated above in respect of [weather conditions]."

e. (pg 3) "[Extent and value of previous reconnaissance] is again neglected for the reasons applicable to [weather and training]."

f. While the statistical analysis presented in this report was "state of the art" at the time the report was written, some of the more recent methods may reveal additional characteristics of these data.

g. It is not quite correct to say that "The topographical characteristics of the theatre of war" have been "found to have a significant influence on rates of advance." The theatre of war *was* found to have a statistically significant effect on rates of advance, but just what aspects of the theaters of war caused this difference were not actually evaluated. So attributing it (solely) to terrain is highly speculative.

h. The extent to which the War Diary entries suffered from a potential vicious circle is not known. The vicious circle referred to here is the one that bases judgmental

assessments of such factors as enemy opposition and closeness of the terrain at least in part upon the rate of advance achieved. That is, it is easy to slip inadvertently into judging enemy resistance as heavy *because* the rate of advance was low, and then to turn around and argue that the rate of advance was low *because* enemy opposition was heavy. This sort of vicious circle can be broken only if the assessments of enemy resistance and rate of advance are completely independent of one another. Without detailed knowledge of the particulars of the case, it is hard to tell whether they are or aren't.

i. On the basis of inspection of the advance distance tables, it appears that there is a significant bias in the direction of reporting attacks that gained ground as opposed to those that did not.

RAND-1953

1. Document:

a. Title: The Rate of Advance of the Front Line in Some World War II Campaigns

b. Author: Mulholland, R. P., and R. D. Specht

c. Date: 16 April 1953

d. Organization: The RAND Corporation

e. Number: RM-1072

2. Objectives and Scope:

a. Motivated by issues arising in wargames, this document aims to present some historical data on the velocity of the front line and strengths of the opposing forces in the European and Mediterranean Theaters of World War II.

b. The specific operations studied are:

- (1) Sicily, D to D+30
- (2) Salerno to Winter Line (Italy), D to D+60
- (3) First US Army, Normandy to St. Lo, D to D+40
- (4) Battle of the Bulge, D to D+40
- (5) First US Army, Breakout to the Westwall, D to D+120
- (6) Seventh US Army, October 1944 to February 1945, D to D+150
- (7) European Theater of Operations, D to D+300

3. Using the Following Data Sources: (pg 9) "These data are taken from the After Action Reports and Histories of the various Allied Armies and from other documents listed in the Bibliography." [Mostly US Army Operations Reports from WWII.]

4. Distance Defined As: (pg 9) "Rates of advance are estimated from the situation maps of the campaigns."

5. Time Interval Defined As: What calendar dates the authors intended to include in their intervals from D to D+(whatever) are never explicitly stated.

6. Situational Descriptors Defined As:

a. (pp 8-9) "We ignore terrain, climate, initiative, logistic support, air support, the tactical situation, quality of personnel and equipment, mobility, etc., and seek such gross relation as may exist merely between the Allied and Axis strengths and the rate of advance of the battle line. The strength of each side is measured by the number of equivalent divisions in the line; this number is corrected by such numerical values for manpower and estimates of equivalent strength as we could find."

7. Summary of Conclusions Regarding Advances:

a. (pp 10-11) "We observe that [the relative strengths and the velocity of the front for the campaigns considered] are related only in a very gross way. If, for purposes of a mathematical model, one wants a formula with numbers, then we suggest that two such formulas be used both in order to bracket much of the observed data and to find out how sensitive various conclusions from the model are with respect to the position of the front line. Our own nominations for these two formulas are as follows:

Velocity-Strength Relation A:

$$V = 8 \frac{M-M'}{M+M'}$$

Velocity-Strength Relation B:

$$V = 30 \left[\frac{M-M'}{M+M'} + \frac{1}{3} \right] \quad \text{for } (M/M') \leq 1/2$$

$$V = 0 \quad \text{for } 1/2 \leq (M/M') \leq 2$$

$$V = 30 \left[\frac{M-M'}{M+M'} - \frac{1}{3} \right] \quad \text{for } 2 \leq (M/M')$$

"In these equations we denote by V the velocity of advance (or retreat, if V is negative) of the front line (measured in miles per day) and by M and M' the strengths of the opposing forces. In Relation B the battle line is held fixed unless one side is stronger by at least a two-to-one ratio; the unopposed rate of advance is 20 miles/day. ... Figures 9 through 14 [note reproduced here] show, for the campaigns considered above, the historical progress of the battle line as well as that predicted by using the velocity strength relations A and B."

8. Comments and Critique:

a. This is an important study, and it appears to be the first to propose a specific functional relation, founded upon historical analysis rather than speculation, for the effect of force ratio upon rate of advance.

b. This report presents its data only in graphical form. Consequently, specific values are no longer readily recoverable.

c. The manner in which equivalent strengths are obtained is somewhat obscure. Apparently, the number of divisions "in line" on each side was used, unless information suggesting a modification of that value to yield "equivalent divisions" was available. The operations studied are very large indeed, so the strength appears to be that for the entire theater, while the advances would appear to be those of the leading elements only. So the results should not be "scaled down" to lower echelons, such as divisions, brigades and battle groups, or battalions unless further study shows that is proper.

d. The degree of agreement between the formulas and the data is not actually very good, as illustrated by this study's own Figure 8 (pg 19). It is possible that some—it is uncertain how much—of the agreement (such as it is) arises from confounding the strength of the attacking forces with their advances (since both were increasing with calendar time), or with correlations (redundancies) among the various operations considered. For example, it would seem that operation 2b(7) (European Theater of Operations, D to D+300) merely reflects the results of operations 2b(3) through 2b(6), and so is hardly independent of them.

HULSE-1954

1. Document:
 - a. Title: Movement
 - b. Author: Hulse, COL Allen D.
 - c. Date: 9 August 1954
 - d. Organization: Combat Operations Research Group
 - e. Number: Staff Memorandum SM-22-CORG
2. Objectives and Scope:
 - a. The purpose was to examine historical data and review the actions played in the CODEM war game in order to improve the modeling of movement.
 - b. Nineteen examples are given of advances made in WWII by US armored divisions or mixed task forces within those divisions (chiefly armored battalions or combat commands). Of these, 11 were from NW Europe in 1944, 5 from NW Europe in 1945, and 3 from Italy in 1944.
3. Using the Following Data Sources: Unit After-Action Reports and various volumes of the series History the US Army in World War II (the "Green Books").
4. Distance Defined As: Unspecified, but presumably displacement of the FEBA
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As:
 - a. Terrain: Characterized as moderately open, close, mountainous but no objective definitions of these are provided.
 - b. Weather: Clear, mild, cold, snow, fog, rain, misty, fair—again objective definitions are not provided.
 - c. Type action: Pursuit, limited objective attack, exploitation of a breakthrough, seizure of a deep objective after breaking out of a bridgehead, attack through infantry to seize a deep objective.
 - d. Enemy strength: Very light resistance, heavy, moderate—again without objective definitions.
 - e. Friendly casualties: (Seldom known)
 - f. Enemy casualties: (Unknown in all cases)
7. Summary of Conclusions Regarding Advances:
 - a. (pg 3) "It is worthy of note that deep armored drives in enemy rear areas with scattered, disorganized resistance netted on the average of 25-30 miles per day. There are examples of individual daily gains of up to ninety miles. In these cases, however, all resistance was by-passed, no containing forces were left in the rear, and the leading elements were light, highly mobile reconnaissance units. ... In all of these historical examples, it should be remembered, the advances were made with air support on call, column cover, and/or preceded by heavy air strikes. Interference from enemy air was insignificant."

b. (pg 4) "Capability of armored units to move across varied types of terrain, unopposed, should be studied, and up-to-date data obtained ... Capability of type combat units to gain ground under varying conditions of enemy resistance and terrain need additional research and analysis."

8. Comments and Critique:

a. This is an important study, if for no reason other than the elaborate wargaming rates of advance structure that was erected upon it and its companion study by LTC Parsons (see our summary PARSONS-1954). These were among the first attempts to derive from historical study specific quantitative rules for determining the rates of advance of such units as armored battalions and combat commands. That they were not entirely satisfactory is hardly surprising under the circumstances. Nevertheless, they were quite an improvement over the methods previously used by the US Army wargaming community (see, for example, the background described in LTC Parsons' paper, and reproduced in connection with our summary PARSONS-1954).

b. This is a preliminary quick study to determine what can be done in the way of collecting and summarizing historical combat data for use in wargames and analyses. Wainstein has also remarked on that fact, and has provided a detailed critique of Hulse's paper (see our summary WAINSTEIN-1973b). The chief criticism is that the findings overgeneralize from a narrow data base.

PARSONS-1954

1. Document:

- a. Title: Military Unit Rates of Advance in Attack
- b. Author: Parsons, LTC Norman W.
- c. Date: 14 September 1954
- d. Organization: Combat Operations Research Group
- e. Number: Staff Memorandum SM-29-CORG

2. Objectives and Scope:

a. (pg A-2) "It has seemed apparent that there is a general lack of information regarding the actual rates of advance of military units in an attack against an enemy. This lack of information has been noticed in map problems presented in various service schools and in war games and battle planning activities. It seems that in the majority of cases the rate of advance of an attacking unit is considered to approximate the rate of movement in an administrative march cross country, without consideration for the various types of terrain included in the general term "cross country." Casual examination of narrative accounts of military operations indicates that such a rate of advance is unrealistically high. It is believed that more accurate knowledge of factual rates of advance is required in order to permit more realistic map problems and battle plans. [Accordingly, in this paper] the problem is to determine the rates of advance of infantry units in attack under various conditions of terrain and enemy resistance."

b. Data are reported on 33 examples of successful attacks by infantry battalion-sized forces supported by artillery and tanks. Apparently, successful attacks are those that reached their intended objective (cf. item 4, below). Unsuccessful attacks were not tabulated, although pg A-2 remarks that "It should be noted that [in the records consulted] there were many unsuccessful attacks by the same units in the same general terrain and against the same general types of enemy resistance. This analysis does not consider the probability of success of any given attack under the conditions tabulated."

c. Of the 33 examples, 3 are from Guadalcanal, 10 are from Italy, and 20 are from NW Europe (specifically, 14 from the Cherbourg Peninsula/St. Lo region, and 6 from the Moselle River/Hürtgen Forest region).

3. Using the Following Data Sources: Various Dept. of the Army History Division reports, and military intelligence reports of the War Department.

4. Distance Defined As: (pg 4) "The analysis considers only the average rates of advance from the line of departure to the objective *when the attack was successful* [emphasis added]."

5. Time Interval Defined As: Unspecified, but presumably the time from line of departure to the objective.

6. Situational Descriptors Defined As:

a. Terrain: Open (lightly wooded, slightly rolling, elevation changes less than 30 meters per mile and not more than 25 percent woods cover); moderately open (wooded and rolling, elevation changes 30 to 50 meters per mile or 25 to 50 percent woods cover); moderately close (wooded and hilly, elevation changes 80 to 100 meters per mile or 50 to 75 percent woods cover); mountainous (elevation changes over 300 meters per mile)

b. Type action: River crossing, regimental attack, etc.

- c. Artillery support: Number of battalions
- d. Enemy strength and resistance: Number of enemy units (Battalions, Companies, etc.) given where available; otherwise characterized as light, none, very heavy, etc.
- e. Weather: Cold, rainy, clear, etc.
- f. (pg 2) "Other factors which have a bearing on rates of movement, such as morale, fatigue, extent of prior planning and reconnaissance, amount of preparation and briefing, and similar items, although having important effects, cannot be separated for consideration because of the lack of data."

7. Summary of Conclusions Regarding Advances:

- a. (pg 4) "An attempt has been made in Table 5 to provide generalized average figures for the rates of advance to be expected in the various combinations of terrain conditions and enemy strengths and degrees of resistance. The spread of figures applicable to each general situation is in recognition of the variations due to morale, fatigue, type positions, level of artillery support and other factors. It is proposed that these average figures be used in war games and map problems with due consideration for the additional variable factors."
- b. Values in Table 5 range from 110-200 yards per hour for infantry battalions in mountainous terrain and very heavy resistance (force ratios of 2/1 or less), to 1,400-2,500 yards per hour for infantry battalions in open terrain and no enemy resistance. (It is interesting to compare this range to that reported by the BAORG study summarized above as BAORG-1952, i.e., 235 yards per hour to about 1,290 yards per hour.)

8. Comments and Critique:

- a. This supplements Hulse's paper (see our summary HULSE-1954) on armored unit rates of advance by giving information on infantry unit rates of advance. Both Hulse's and Parsons' papers were pioneering efforts. They substantially improved upon the prevailing state of the art in modeling movement in wargames and other US Army studies, and inspired many subsequent models of movement in land combat operations.
- b. (pg 3) "In studying Table 3 there is some suspicion that the description of the enemy resistance may include some element of description of the difficulties of the terrain." If so, this gives rise to the vicious circle described in our summary BAORG-1952. It is also possible that the defender may choose to defend more strongly at places where the terrain is difficult. Either deliberate defender choice or the vicious circle would induce a statistical confounding and correlation of the degree of enemy resistance with the difficulty of the terrain.
- c. Parsons has data on a total of 33 battles. The recommended values in his Table 5 span a total of 25 cases (5 each for Type Terrain and Amount of Enemy Resistance), so there are on the average just slightly over one data point for each category in the table. This obviously is insufficient to provide much confidence in the statistical reliability of the results.
- d. This is a preliminary quick study to determine what can be done in the way of collecting and summarizing historical combat data for use in wargames and analyses. Wainstein has also remarked on that fact, and has provided a detailed critique of Parsons' paper (see our summary WAINSTEIN-1973b).

1. Document:

- a. Title: Rates of Advance in Land Attack Against Unprepared Forces
- b. Author: Andrews, Marshall
- c. Date: August 1960
- d. Organization: ORO
- e. Number: AD-243 938

2. Objectives and Scope:

a. (pg iii, Introduction) "In the course of study for Project SANDY of probable force requirements generated by the occurrence of war in various parts of the world, it became necessary to employ data on rates of advance under certain conditions of attack. A diligent search of manuals and other literature failed to discover the existence of a suitable factor generally accepted for planning purposes. The present study was therefore undertaken to supply this want."

b. The following operations are examined:

- (1) Sherman's March, Atlanta to Savannah, Georgia, 1864
- (2) Kluck's Invasion of Belgium and France, August-September 1914
- (3) Austro-German Advance from Caporetto, November 1917
- (4) German Invasion of Holland, Belgium and France, May 1940
- (5) Advance of German 4th Army from Somme, June 1940
- (6) German Invasion of Yugoslavia and Greece, April 1941
- (7) German Invasion of Russia, June-December 1941
- (8) Japanese Advance through Malaya to the Strait of Johore, 1941-1942
- (9) North Korean Invasion of South Korea, June-August 1950
- (10) Wavell in North Africa, 1940-1941
- (11) Rommel I in North Africa, 1941
- (12) Auchinleck in North Africa, 1941
- (13) Rommel II in North Africa, 1942
- (14) Montgomery in North Africa, 1942-1943

3. Using the Following Data Sources: Primarily Esposito, BG Vincent J. (Ed.), "The West Point Atlas of American Wars," 2 Vols., Praeger Publishers, 1959.

4. Distance Defined As:

- a. Distance between plotted phase lines.
- b. (pg 8) "These results do not, nor could they, take into consideration actual road miles covered by major or subordinate units. Distances used are in terms of distance covered over stated periods."
- c. (pg 8) "No attempt has been made to include vertical distance in the total miles traveled."
- d. (pg 9) "In each case selected the criterion for distances advanced was attainment of the objective or cessation of the advance. It was not considered whether fractions of the command charged with the operation, or the entire force, had closed up on the objective so long as the objective itself was realized. On the other hand, penetrations by small subordinate units, such as reconnaissance elements, beyond the final phase line were disregarded."

5. Time Interval Defined As: Not specified, but presumably the times used to label the phase lines.

6. Situational Descriptors Defined As: Desert, mountainous, or neither. But these terms are not objectively defined.

7. Summary of Conclusions Regarding Advances:

a. (pg 2) "... the attacks in WWI began slowly as enemy defenses were methodically breached, and gained momentum after the breakthrough. On the other hand, the charts indicate that in general the armored assaults of WWII opened with rapid penetrations, followed by progressive slackening of the rate of advance with time and distance until objectives were attained or the attacks were halted."

b. (pp 2-4)

"1. The average rate of advance for armies [when the attack initiated a war or a major campaign and tactical surprise and unreadiness or great relative weakness of the defender were important factors] appears to be approximately 9.69 mi/day for distances up to 300 miles and periods up to 30 days.

"2. The minimum, maximum and average rates of advance, in mi/day, under various conditions appear to be:

	<u>Min</u>	<u>Max</u>	<u>Average</u>
Sherman and WWI	3.95	9.06	7.00
WWII	8.27	17.44	11.47
Desert Attacks	4.19	10.85	6.97
Mountain Attacks	7.03	11.3	8.79

"3. For distances after 300 miles and times after 30 days the average rate of advance in modern war falls off sharply. In the 1941 campaign in Russia the average German rate of advance in the first 300 miles was 15.6 mi/day; for the entire campaign of 165 days, with penetrations up to 800 miles, the rate was 4.16 mi/day.

"4. The apparently typical loss of momentum in motorized operations seems to be the result generally of the combination of 3 factors directly associated with modern techniques:

a. The logistical burden imposed by motor vehicles and rapid-fire weapons, a burden which increases with time and distance.

b. Battle attrition of combat vehicles and crews, and operational attrition of all vehicles.

c. Early and heavy stiffening of resistance as troops are more rapidly redeployed for defense.

"5. A partial response to the limitation discussed in 4 above may lie in development of field trains to accompany assaulting forces with Class III and Class V supplies for the entire campaign, and accompanying replacement vehicles and personnel to compensate for attrition. Some of the requirement might be met by air resupply."

8 Comments and Critique:

a. As indicated in its title, this is a study of rates of advance by forces that are but lightly engaged. I suspect that earlier on various staff studies may have collected similar data and made some sort of informal or even statistical analysis of it (witness the fairly definite march rate planning factors supported by various march rate examples Clausewitz put forward, as in our summary CLAUSEWITZ-1832, but Andrews' study is the first systematic effort that has come to my attention. Andrews' rates for WWII and similar motorized rates of advance do not seem to have improved much upon those mentioned by Clausewitz.

b. I have not always been able to reconcile the times quoted by Andrews with the dates he gives.

c. Parts b and c of Andrews' Conclusion 4 apply with equal force not only to "modern motorized operations" but also to any large force movement over extended distances requiring long lines of communication, and part a of it applies to any large force requiring food, water, forage/fuel, etc.

BEKKER-1962

1. Document:
 - a. Title: Theory of Land Locomotion
 - b. Author: M. G. Bekker
 - c. Date: 1962 (2nd printing)
 - d. Organization: University of Michigan Press, Ann Arbor, MI
 - e. Number: NA
2. Objectives and Scope: Bekker's text aims to uncover the fundamental principles governing locomotion on land, and to give methods for analyzing such locomotion from an engineering design point of view.
3. Using the Following Data Sources: Gabrielli, G., and Th. von Karman, "Maximum Speed and Specific Power of Vehicles," ATA, Turin, 15 January 1948.
4. Distance Defined As: Unspecified, but evidently actual distance traveled by a single vehicle or animal.
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As: Unspecified
7. Summary of Conclusions Regarding Advances:
 - a. (pp 62-66) Maximum, or limiting speed, is related to the power/weight ratio in the following fashion:
$$P/mg = 0.001v^2$$
where P = motive power (in horsepower), mg = weight (in tons), and v = speed (in miles per hour). According to Bekker, "... no airplane, ship, or any other vehicle seems to have crossed [this limit, which is] closely approximated by wheeled vehicles running over hard surfaces."
8. Comments and Critique: This is a remarkable finding, but its implications for military rates of advance are not clear. An example effort to apply fundamental terrain/vehicle engineering methods to analyze the movement of large land combat forces is described in Robinson, J. H. and T. C. Dean, "Tactical Mobility Study," Waterways Experiment Station, WES/TR/GL-84-11, Corps of Engineers, Vicksburg, Mississippi, September 1984, AD B-087-564L.

BEST-1966

1. Document:
 - a. Title: Casualties and the Dynamics of Combat
 - b. Author: Best, Robert J.
 - c. Date: March 1966
 - d. Organization: RAC
 - e. Number: RAC-TP-185
2. Objectives and Scope: Best deals mainly with casualties and their effect upon various aspects of combat dynamics. Movement is but one of the aspects of combat dynamics of interest to him.
3. Using the Following Data Sources: Varied.
4. Distance Defined As: Unspecified
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As: Unspecified
7. Summary of Conclusions Regarding Advances:
 - a. "The greater the casualties sustained by attacking battalions—or the greater the opposition encountered—the smaller is their rate of advance."
 - b. "Slackening of offensive progress is not accompanied by comparable decreases in casualties or volumes of support fire."
 - c. "A number of statistical correlations have been found between casualties and other quantities related to maneuver units. Generally it is not at all clear that these quantities are directly related, and if they are, which is the independent (i.e., causative) variable. ... The apparent and seemingly causal decrease in rate of advance with increases in casualties has been shown to be largely a matter of increased duration. The casualties *could* be responsible for this. ... Yet casualties *could* also increase as a result of prolonged exposure, and increased duration *could* be determined entirely by other factors."
 - d. "As the rate of German advance generally diminished [in Operation Barbarossa] and the degree of combat involvement increased, the overall casualty rate remained fairly steady. The casualty rate for the engaged units must therefore have decreased. Did the casualties brake the advance or was the primary reason [something else]?"

"Doubt about the causative influence of casualties also arises from their increase with friendly support ... Finally there is the direct correlation between casualties and definable indexes of combat activity."
 - e. "The very fact that units sometimes, if only rarely, suffer catastrophic casualties just proves the potentiality of fire. So far as weapons of conventional type are concerned, further increases in firepower would only further accentuate these changes. The patterns of combat would remain essentially the same."
8. Comments and Critique: Best is an exceptionally astute student of military operations. His observations and cautions are well-taken.

OVERHOLT-1970

1. Document:

- a. Title: Statistical Analysis of Korean War Data—Spring 1951
- b. Author: Overholt, J. L.
- c. Date: April 1970
- d. Organization: Center for Naval Analyses
- e. Number: Naval Warfare Analysis Group Study 64, AD-869 481 (Volume IX of the series of CNA reports on the Study of Land/Air Tradeoffs (SLAT))

2. Objectives and Scope:

a. (pg ix, Summary) "This volume [of the SLAT study series], concerned with the Korean War, describes attempts to relate the strengths of opposing U.N. North Korean/Chinese Communist forces, including fire support, with the ground gained and casualties on both sides. The objective is to determine, by statistical techniques, relationships among various kinds of battle data recorded each day by divisions. These were intended to provide guidance in the TWSP simulation ..."

b. (pg ix, Summary) "The data for May 1951 is used because it is readily available and includes various kinds of combat in a period when sectors were relatively quiet, the thrust of the Chinese Communist Army near the Soyang River, and the counterattack of U.N. forces. In this period, there were no large break-throughs or amphibious landings."

3. Using the Following Data Sources:

a. (pg ix, Summary) "The data consists of daily friendly and enemy strengths and casualties in the IX and X Corps in central Korea, air and artillery support of US and ROK divisions, and changes in territory. The enemy had no artillery or air support in this sector during this period. The data on small arms, machine guns, mortars, tanks, etc., though not available for either side in division records, is assumed to be proportional to the strengths and to such ordnance expended in World War II. Reserves were introduced continually by U.N. forces, intermittently in the form of new divisions by the Communists."

b. Official after-action reports and operational summaries were used as the principal data sources.

4. Distance Defined As: (pg. 7) "The ground gained (in area) was measured by planimeter from the change that occurred from one day to the next for each division. We obtained the average gain or loss by dividing the area by the front length." However, Annex D-1 describes the "Variables Used in the Regression Analysis" as "the territory measured in square kilometers acquired or relinquished by a friendly unit during the time period under consideration," and expresses the value used in the regressions as this value divided by 10.

5. Time Interval Defined As: Daily intervals (presumably starting around mid-night)

6. Situational Descriptors Defined As:

a. (pg 11) Fire support refers to the artillery and air ordnance delivered in support of each division. Light artillery is expressed in numbers of rounds of ammunition 105 mm and larger; artillery support to divisions, in tons per mile of front.

b. (pp 11-13) Data were collected on three types of air support: Close air support, Sorties by light bombers, and Sorties by heavy bombers. Close air support consists of ordnance sorties delivered under ground or air control to targets beyond the forward bomb line. The ordnance delivered by light bombers within 15 miles of the battle line in support of each division was taken as fire in support of ground troops. Data were also obtained on ordnance delivered in support of corps and army. Heavy bomber support consists of B-29 sorties supporting the divisions, corps, and army.

c. (pg 21) "The battles are described by variables already mentioned—the strengths, casualties, and firepower of the opposing sides—and such others as weather, terrain, tempo of fighting, the effects of pre-bombardment and of movement of adjacent units, and the decisions of the opposing commanders to attack, withdraw, or hold."

7. Summary of Conclusions Regarding Advances:

a. (pp xii-xiii, Findings) "Ground gained correlated most closely with casualties, and fewer friendly losses occurred during advances than during retreats. Gains by friendly forces were associated with increases in air sorties during both patrols and heavy attacks. The poorer equations (low R^2) for friendly gains may reflect differences in enemy resistance either from dug-in positions or during rapid evacuations. Enemy gains occurred during a deficiency of heavy bomber sorties. They also occurred when our forces were massed and when our forces received the support of light bomber sorties—probably measures of our response to the anticipated attack."

b. (pg 26) "The important terms [in the regression equation for ground gained] were friendly strength, ground gained by adjacent units, and friendly casualties. The last is the largest term [i.e., has the largest coefficient], and where it was deleted, friendly strength appeared important. Fire support was not significant in any equation. The highest R^2 was 0.59 for the 3-day averaged data."

8. Comments and Critique:

a. This was a major and apparently one of the earliest efforts to obtain enough detailed data on real combat operations that they could be compared to the outcome of wargames of those same operations. The importance of such efforts is obvious.

b. (pg i, Abstract) "Though the work is indicative, it is limited by the poor quality of information about enemy strength." (pg 7) "Enemy strength was measured from the order of battle, as derived by intelligence sources. Only the elements of the Communist division opposing each friendly division are available." (pg 11) "The enemy strength data was poor. The order of battle was derived from captured prisoners; when the enemy was attacking, little or no data was available because no prisoners were taken. Even where such intelligence was available, it was often inaccurate because the enemy troops were sometimes transferred and did not know the designations of their new units when interrogated. Analysis after the war disclosed that the number of enemy troops was frequently underestimated because the Chinese Communists were trained for long night marches, averaging 15 to 20 miles a night for two or three weeks, and were taught to stand stock-still when aircraft were heard or sighted. U.N. forces discounted sightings by South Korean civilians. Finally, known enemy casualties were not subtracted from the order of battle. [In one of the author's attempts to improve the quality of enemy strength information] simple subtraction of casualties from strength figures led to inconsistencies." (pg 46) "The enemy strength and casualty data should be examined more critically to see whether estimates are made in the same manner by various forces. Apparently the 2nd Army Division estimated greater casualties than the 1st Marine Division. The casualties may be [i.e., may have been] estimated from the quantity of ordnance fired and may be fallacious."

c. It is very difficult to judge the validity of the statistical methods used. All too often, the exact forms of the equations are not clear. The basic numerical data on which the regressions are based is not provided, although it may be available in other volumes of the SLAT series. Frequently it is not clear how the independent variable terms were selected (i.e., *ab initio*, or by a form of stepwise regression).

d. There may be a problem with inflated R^2 values caused by repeated multivariate regressions and stepwise regression procedures. For a good discussion of the potential perils of such practices, see (1) Freedman, D. A., "A Note on Screening Regression Equations," *The American Statistician*, 37, 152-155 and (2) Freedman, L. S. and David Pee, "Return to a Note on Screening Regression Equations," *The American Statistician*, 43, 279-282. The extent to which this study suffers from such potential pitfalls cannot be ascertained because the report does not give enough information on the exact procedures used and the order in which they were done.

MADER-1971

1. Document:
 - a. Title: A Review of the Origin and Development of Movement Rates Used in Army War Games
 - b. Author: Mader, Donald W.
 - c. Date: 28 January 1971
 - d. Organization: Research Analysis Corporation
 - e. Number: Presented to the DA "FEBA Movement" Seminar. Later published as an Internal Memorandum, Research Analysis Corporation, May 1971. (Also published in "Review of Selected Army Models," US Dept. of the Army, May 1971.)
2. Objectives and Scope:
 - a. This paper's purpose is to trace the development of rates of advance tables used in war games from the Hulse and Parsons papers on rates of advance (see our summaries HULSE-1954 and PARSONS-1954) to circa 1971.
 - b. No new data on actual operations is used.
3. Using the Following Data Sources: Same as those used by Hulse and Parsons
4. Distance Defined As: Same as in Hulse and Parsons
5. Time Interval Defined As: Same as in Hulse and Parsons
6. Situational Descriptors Defined As: Same as in Hulse and Parsons
7. Summary of Conclusions Regarding Advances:
 - a. Specific conclusions are not stated, but the implication is perfectly clear: wargame rates of advance have been created by overgeneralization and overextrapolation of Hulse's and Parsons' original data well beyond a point justified by such a limited database.
 - b. (From the "Concluding Remarks" made by Lawrence J. Dondero) "I think it is fair to say that Mr. Mader's paper was a searching and rather conclusive demonstration that the "rate of advance" factors now in use in most theater simulations are based on a very limited amount of historical research. ... It seems reasonably clear at any rate that in 15 years there hasn't been too much significant improvement or alteration of the original constructs of Hulse and Parsons."
8. Comments and Critique: The conclusions were certainly correct at that time.

MEFORD-1971

1. Document:

- a. Title: Rates of Advance as a Function of Force Ratio
- b. Author: Warner, C. A.
- c. Date: May 1971
- d. Organization: Appendix G of RAC, "Methodology for Force Requirements Determination (MEFORD)," RAC-R-121, Research Analysis Corporation, McLean, VA May 1971
- e. Number: AD-515 716L

2. Objectives and Scope:

a. This study examines the background and validity of rates of advance/force ratio factors employed in the dynamic analysis of ground warfare operations. The focus is on the validity of a relation between rates of advance and force ratios.

b. Data is given on 37 engagements, of which 9 are from Italy, 2 from the Lorraine campaign, 15 from Okinawa, and 11 from Korea.

3. Using the Following Data Sources:

- a. Historical Evaluation and Research Office (HERO), "Average Casualty Rates for War Games, Based on Historical Combat Data," February 1967.
- b. Historical Evaluation and Research Office (HERO), "Historical Trends Related to Weapon Lethality," three volumes, 1964.

4. Distance Defined As: Unspecified

5. Time Interval Defined As: Unspecified

6. Situational Descriptors Defined As: For the most part, situational descriptors are not used. However, three different methods of computing force ratios were used. In the first, the ratios of the personnel strengths was used. In the second, the ratios of firepower potentials. In the third, HERO's QJM lethality indices were used.

7. Summary of Conclusions Regarding Advances:

a. (pp G-5 and G-29 to G-30) "Daily advances made in the engagements studied were not closely correlated with mean attacker/defender force ratios. There was no consistent relationship. ... The present base for rates of advance tables is inadequate. Advances in the 37 WWII and Korean War engagements studied do not support current tables and curves in which rates of advance are a function of attacker/defender force ratios. These engagements do not, in fact, provide evidence of a clear relationship between advance and force ratio. ... This paper does not validate any assumed dependence of rates of advance on force ratio. Neither does it deny that some general and orderly dependence may exist. ..."

b. "If games and simulations are to continue to be used as a tool in developing force composition and size, and if rates of advance are to continue to be a significant measure of force effectiveness, it is imperative that research be undertaken to develop an empirical basis for force ratio/advance rate curves."

8. Comments and Critique:

a. This seems to be among the first studies to question the validity of a more-or-less direct dependence of rate of advance on force ratio and to marshal specific historical evidence to support its position. Its cautions about the validity of force ratio/advance rate curves seem warranted by the evidence presented.

b. However, the values for the various engagements used in this report frequently differ from those used in Pearsall (see our summary PEARSALL-1972), as well as those reported elsewhere. The reason for these discrepancies is not clear.

PEARSALL-1972

1. Document:
 - a. Title: Casualty Rates and Opposed Advance
 - b. Author: Pearsall, Edward S.
 - c. Date: January 1972
 - d. Organization: Institute for Defense Analyses
 - e. Number: Working Paper No. 11 (presented to Improved Methodologies for General Purposes Planning: New Methods Study)
2. Objectives and Scope:
 - a. This paper analyzes statistically a database of battles assembled by the Historical Evaluation and Research Office (HERO), with the aim of showing that the data are consistent with a simple model of combat. Specifically, that the rate of opposed advance depends only upon the defender's posture.
 - b. The database consists of 97 operations, the first 37 of which are the same as in the MEFORD study (cf. Warner, May 1971, above). All of the remaining 60 are from Italy (9 from the Salerno Campaign, 20 from the Volturno Campaign, 11 from the Anzio Campaign, and 20 from the Rome Campaign).
3. Using the Following Data Sources:
 - a. "Use of Historical Data in Evaluating Military Effectiveness," Historical Evaluation and Research Organization, 1970.
 - b. "A Study of the Relationship of Tactical Air Support Operations to Land Combat," Historical Research and Evaluation Organization, 1971.
 - c. Warner, C. A., "An Examination of Rates of Advance as a Function of Force Ratios for Ground Combat War Games," published as Appendix G of "Methods of Force Requirements Determination (MEFORD)," Research Analysis Corporation, 1970.
4. Distance Defined As: Unspecified
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As:
 - a. Terrain: flat, rolling, rugged
 - b. Defense posture: fortified, prepared, hasty, delay, withdrawal
 - c. Strength: average attacker and defender personnel strength, attacker and defender lethality indices computed according to the QJM method
 - d. Casualties: attacker and defender casualty rates in percent per day
 - e. Victor: successful defense, unsuccessful defense

7. Summary of Conclusions Regarding Advances:

a. (pg 19) "Our standard equation for the rate of opposed advance, D , includes as explanatory variables only the previously defined dummy variables for defense posture. X_k , $k = 1, \dots, 5$. For each observation in the sample the dummy variable corresponding to the appropriate defense posture is set to one while the remaining variables assume a value of zero. The equation is specified in linear form:

$$D = \sum_{k=1}^5 \gamma_k X_k$$

[In words, this means that the rate of advance depends solely upon which defensive posture was used and not on any other factors such as force ratio, weather, or terrain.]

b. (pp 19-21) The least squares estimates of the coefficients (in units of kilo-yards per day) are as follows:

Variable	Estimated Value	Standard Error
Fortified	1.422	1.339
Prepared	0.826	1.367
Hold	1.490	1.344
Delay	3.108	1.344
Withdraw	21.423	1.275

Thus, the rate of advance is 1.422 kilo-yards per day when the defender is in a "fortified" defensive posture, 3.108 kilo-yards per day when the defender is in a "delay" defensive posture, etc.

c. (pp 19-24, *passim*) "The correlation coefficient of 0.727 indicates that our standard equation provides a statistically respectable explanation of the data for the opposed rate of advance. Equally important, the estimates of the coefficients γ_k , $k = 1, \dots, 5$ conform roughly to expectations. The first three defense postures imply no planned movement by the defender. As we might expect, attacks against defenders assuming these postures cannot be expected to yield a positive rate of advance with a high level of confidence. However, an attack against a defender who is delaying or withdrawing from combat can be expected to yield ground at a positive rate. Moreover, the 21,423 yards per day expected to be surrendered by a withdrawing defender is significantly greater (to say the least) than the 3,108 yards surrendered on average during a delayed withdrawal."

"The regression results shown in columns 2-8 of Table III [not reproduced here] suggest that the other variables for which observations are available in the HERO publications add little to the statistical quality of the standard equation. [Specifically, we note the following findings of Table III]:

"(1) [When the ratio of attacker to defender manpower is added as an explanatory variable its] estimated coefficient is not significantly different from zero. Worse, its negative sign is impossible to conceptually justify.

"(2) Addition of the ratio of attacker to defender firepower indices ... produces about the same result as addition of the manpower ratio ... The estimated coefficient is insignificant and implausibly negative.

"(3) The addition of the attacker's casualty rate ... does not significantly improve the statistical fit.

"(4) The defender's casualty rate contributes little as an explanatory variable.

"(5) [Regarding] the effects of introducing terrain as a contributory expositor; ... rolling terrain is neutral, i.e., does not increase or retard the rate of advance. The coefficients for flat and rugged terrain suggest that both conditions retard the rate of advance. However, the coefficients are not significant in either case.

"(6) Their [i.e., the dummy variables indexing the several campaigns or theaters of operation] introduction into the equation for the rate of opposed advance produces a rather marginal case for their inclusion. Taken individually, none of the coefficients are different from zero at a high level of significance. However, as a group the coefficients are significant, that is, it is unlikely that they could all be simultaneously equal to zero.

"(7) Whether or not an engagement is a success from the defender's point of view does not appear to contribute to our statistical explanation of the rate of opposed advance."

8. Comments and Critique:

a. If, as claimed, defensive posture is virtually the sole determinant of rates of advance, then force ratios cannot have a major influence on rates of advance. This paper is important for raising this issue so clearly.

b. (pg 23-24) "However, the high coefficient of correlation, R^2 , of 0.727 is somewhat misleading. ... A large part of the variation in the dependent variable [i.e., rate of advance] can be traced to a few rapid delays and withdrawals. Any regression that succeeds in explaining [i.e., in fitting] these cases will have good statistical properties even though it leaves the rate of opposed advance for all other observations largely unexplained. This appears to have occurred with [the regression equation adopted in this study]."

c. The defender's decision to stand or to withdraw was found to be a major factor affecting rates of advance. But no insight is offered on when the defender will choose to stand, and when to withdraw. (pg 24) "Aspects not yet dealt with include: (1) Termination of Engagements: Under what conditions is an attacker forced to abandon an attack as a failure? When does a defense posture become untenable?" Yet another consideration is the possibility that the association found between defensive posture and rate of advance is due to the vicious circle described earlier whereby degree of resistance is statistically confounded with advance rate.

d. The data values used by Pearsall differ from those used by Warner in the MEFORD study (see our summary MEFORD-1971), and from other values for these actions that have appeared in subsequent databases. Moreover, some WWII Italian Theater actions are double-counted because they appear both in the first 37 (borrowed from Warner's MEFORD study) and also in the last 60 of Pearsall's data set. Pearsall appears not to have noticed this—at any rate he does not remark on it.

e. (pg 23, footnote) "... all withdrawals occurred in rolling terrain ..." This may be due to the effect remarked upon elsewhere, of the defender's deliberate avoidance of "easy" terrain in favor of more "difficult" terrain when choosing defensive positions.

f. (pp 25-26) "Several unsatisfactory characteristics of the HERO data and the estimates we have derived from them should also be noted:

(1) "The campaign dummy variables are actually proxies for characteristics of armies and theaters that were not identified and measured by HERO. Systematic differences in the apparent efficiency of armies should eventually be traced to the logistics scarcities, attrition, failures of morale, etc., that caused these differences.

(2) "The defense posture designations adopted by HERO confuse two distinct effects. A fortified defense on the one hand implies a previously prepared and extremely strong defensive position. This should reduce the defender's casualty rate. On the other hand, the fortified defense posture implies no retreat, i.e., no sacrifice of territory to avoid casualties. Our estimates suggest that these two effects about cancel each other."

(3) "It is hard to say just what criteria a balanced sample of modern ground combat actions should meet. Nevertheless it is hard to imagine a set of criteria by which the HERO data could be judged as balanced. None of the engagements took place in terrain that favored the use of armor. In only a few cases is the defender really badly defeated nor does the sample contain many real offensive fiascos. Except for a few of the Korean War engagements, the actions all took place under good or at least fair weather conditions." So there may be a bias favoring advances by the attacker.

g. The study's conclusion in our paragraph 7c(7) above may perhaps be explained by the fact that the defense posture variables (such as Hold, Withdraw, etc.) *already* imply which side won. So adding any additional information on which side won is superfluous.

DESANTIS-1972

1. Document:

- a. Title: Manual War Gaming: An Historical Analysis of Combat Ratio Versus Rate of Advance
- b. Author: de Santis, MAJ Edward
- c. Date: 1972
- d. Organization: Treatise Submitted to the Faculty of the United States Army Command and General Staff College, 1972
- e. Number: NA

2. Objectives and Scope:

a. (pg ii, Abstract) "This investigation was conducted to establish a correlation between combat ratio and rates of advance of two opposing forces on a conventional battlefield. The primary purpose of the research was to verify the data presently being used in the Combat Developments Command Manual Quick War Game (JIFFY)."

b. The operations studied are eighty-four World War II division attacks by US forces in the European Theater of Operations.

3. Using the Following Data Sources: US Army Historical Series (Green Books), supplemented by a few other historical volumes

4. Distance Defined As: (pg 21) "The actual distance of advance of the attacker in each battle analyzed was scaled off the situation map for the corresponding time interval described in the narrative of the battle."

5. Time Interval Defined As: Described in the battle narrative.

6. Situational Descriptors Defined As:

a. (pg 18) Frontal or flank attack by infantry or by mechanized/armored attacks over open, median or close terrain against open, hasty or fortified defenses. [There are $2 \times 2 \times 3 \times 3 = 36$ possible combinations of these factors.]

b. Open, Median, or Close terrain (pg 17). "Open terrain is flat or slightly rolling, with little vegetation, and has a contour interval variation from 0 to 100 meters per kilometer, permitting maximum cross-country movement. ... Median terrain is rolling terrain, lightly covered with trees and other vegetation with a contour interval variation of 100 to 200 meters per kilometer produced by small hills with gentle slopes causing a slight reduction of cross-country movement. ... Close terrain is rough, heavily wooded terrain with a contour interval variation of 200 to 400 meters per kilometer or more. This variation is considered sufficient to cause significant slowing of cross-country movement."

c. Open, Hasty or Fortified Defense (pp 16-17). "An open defensive posture is one in which the defender has not had time to prepare field fortifications of any type and is using only the natural cover and concealment afforded by the terrain. ... A hasty defensive posture is one in which basic field fortifications, obstacles, and minefields have been constructed, normally in less than a 24-hour time period. ... A fortified defensive posture is one in which basic field fortifications have been improved with revetments, overhead cover, additional minefields and other obstacles, and the time of preparation of the position has been in excess of 24 hours."

7. Summary of Conclusions Regarding Advances: (pp 29-31)

a. "Attacker advance should be permitted for combat ratios between 1 to 1 and 2 to 1 as indicated in Figure 5 and 6 [which purport to show rate of advance versus combat power ratio for open, median and close terrain for infantry units (Fig. 5) and for mechanized/armor units (Fig. 6)]."

b. "Actual values of rates of advance for combat ratios above 5 to 1 should be computed when necessary from the power equations given in Appendix K." These equations are as follows:

For infantry attacks over open terrain:

$$Y = 0.0524401X^{1.53482}$$

For mechanized attacks over open terrain:

$$Y = 0.0074379X^{1.9782}$$

For infantry attacks over close terrain:

$$Y = 0.8079X^{0.878979}$$

For infantry attacks over median terrain:

$$Y = 0.140894X^{1.27667}$$

For mechanized attacks over median terrain:

$$Y = 0.264352X^{1.20381}$$

For mechanized attacks over close terrain:

$$Y = 0.140547X^{1.19188}$$

where in each case Y = rate of advance in meters per hour and X = combat power ratio (attacker to defender). The combat power ratio is computed as follows. First, determine the firepower ratio using a weighted firepower score index for each side. Then find the combat power ratio from the firepower ratio and the combat situation from the curves in Fig. 2 for converting firepower scores to combat power ratios according to which of the following combat situations obtains:

- "(1) Open & hasty defense, flank attack
- "(2) Fortified defense, flank attack
- "(3) Open defense, frontal attack
- "(4) Hasty and fortified defense, frontal attack

c. "Based on the historical data evaluated for this study appears that the values of the rates of advance presently used in the JIFFY war game are inflated and should be reduced to those give in Figures 5 and 6."

8. Comments and Critique:

a. This study supports with a statistical analysis of historical data the view that force or combat power ratios have a major, direct influence upon rates of advance. It is nearly unique in this regard. However, it is also nearly unique in using combat power ratios computed for historical battles in basically the same way as in the JIFFY (or any other) wargame.

b. The author claims his equations agree well with the historical data, based on measures of statistical correlation in the 0.982-0.997 range. These correlation coefficients are in fact so extremely high compared to those for most military historical and similar sociological statistics as to raise suspicions.

c. Furthermore, his data are highly correlated, since he has used advances by several of the divisions in a single corps operation as though they were separate (statistically independent) sample points. Moreover, some additional free parameters are sort of "smuggled in" via the conversion of organizational structures to firepower indexes, and their subsequent conversion to combat power ratios via separate curves for various combat situations, and one wonders how much of the correlation is induced by these conversion steps. Since the study uses 84 data points, but 36 possible combinations of factors in addition to two parameters for the combat power ratio curve fit, there are on the average only about $84/(36 \times 2) = 1.2$ data points per freely adjustable parameter. So perhaps the good fit is not so surprising. Moreover, the combat power ratios are confounded with both the defender's posture and the attacker's tactics. So this study's good fits may be statistical artifacts.

d. Most of the historical data used in this study are for US versus German forces in the European Theater of Operations, nearly all in the October to mid-December 1944 time period. This is a very limited basis for the rather wide conclusions stated in the paper.

ORALFORE-1972

1. Document:

- a. Title: Opposed Rates of Advance of Large Forces in Europe (ORALFORE)
- b. Author: Dupuy, Trevor N. and Grace P. Hayes, et al
- c. Date: 28 August 1972
- d. Organization: Historical Evaluation and Research Organization (HERO)
- e. Number: AD-902 830

2. Objectives and Scope:

a. (pg 1, introduction) The study objective was "to broaden the data base, improve the logical structure of current rates of advance tables and determine the influence of factors, in addition to force ratios, on the rates of advance."

"In pursuing the objective HERO's purpose was to provide insight into some of the basic problems of dealing with rates of advance in wargaming and simulations of the US Army by attempting to ascertain whether historical combat experience provides a basis for calculating rates of advance of large forces (divisions and corps); by examining the assumption, accepted as valid in current models and wargames, that rates of advance can be related directly to the force ratios of opposing military forces; and by analyzing the factors that have influenced rates of advance in historical combat, to determine their significance, their relative importance, and their interrelationship. The ultimate result was intended to indicate the feasibility of using historical data to develop rates of advance inputs suitable for use in simulations of modern ground combat.

"By a thorough examination of six operations in World War II, it was also expected that a considerable body of information would be assembled that would throw light on operational processes involved in the movements of large forces in combat."

b. The operations studied (with their code letter abbreviations) are:

- (1) A-German Ardennes-Flanders Offensive, 10-24 May 1940
- (2) B-German Orel to Moscow Offensive, 13 November-7 December 1941
- (3) C-German XL Panzer Corps, Don River to Caucasus, 21 July-23 August 1942
- (4) D-US VII Corps, Argentan to Liege, 13 August-12 September 1944
- (5) E-US XX Corps, Le Mans to Metz, 14 August-14 September 1944
- (6) F-US XII Corps, Saar (Lorraine) Campaign, 8 November-7 December 1944
- (7) (in less detail) German advance into Russia from Poland to Moscow, 1941
- (8) (in less detail) Napoleon's advance into Russia, 1812

3. Using the Following Data Sources:

a. US and German documents in US archives, and selected books. "In some instances gaps in data could be filled by interpolation or extrapolation on the basis of professional military or historical experience."

b. "It proved to be impossible to complete the research and analysis for all six operations within the level of effort and the length of time provided. Problems of locating, translating, recording, and analyzing data consumed more time than was provided, with the result that some of the potential sources could not be completely exploited."

c. "The data immediately available for operations B and C was not sufficient to permit calculation of the relative combat strengths of the opposing German and Russian forces. Nor was it possible within the limitations of this study to do the research in records of British and French forces necessary to secure accurate statistical information for operation A. Consequently the analyses of these operations are based only on the information shown in the matrix. Also, because of changing corps boundaries, it has been necessary to study Operation A only from the point of view of the 7th Panzer Division. In Operation C translation and detailed exploitation of records of the 3d Panzer Division has not been possible, and the analysis has been made entirely on the basis of XL Corps records."

d. For Operation C (from pg. C-61): "No research has been done in Russian sources, and consequently it is not possible to include much information about the Russian strength and performance. Information on close air support on both sides appears to be incomplete. ... For much of this period German casualty data is available only for periods of five to ten days. The daily casualty figures used in the table, except where specific figures are available from other sources, are averages for these periods. ... Since Russian statistics were not available the force ratio has been estimated, with no attempt to do so on a daily basis. ... Since during most of the advance the active elements of the corps were two armored divisions, there is no significant difference in corps rates and division rates, save those caused by averaging of the rates of two different units."

4. Distance Defined As: Not explicitly defined, but apparently based on the displacement of the FEBA trace.

5. Time Interval Defined As: One day, presumably from circa the middle of one night to the next, as this is a common periodic reporting interval.

6. Situational Descriptors Defined As:

a. "[The] intensity of opposition to advance is the historian's estimate from the narrative [account of the action], and from an assessment of relative casualties suffered on each side, of the tenacity of the defender's resistance to the attacker's advance on any given day. It bears no relationship to force ratio, but rather is an effort to reflect the interaction of those advancing and defending elements which were engaged on a given day—elements which were frequently only a relatively small fraction of the total forces available on both sides. Intensity of opposition to advance should not be confused with intensity of combat." Intensity of opposition is characterized as: intense, moderate, slight, negligible. But these terms are not defined in an objectively-measurable way.

b. Weather is characterized as sunny, dry, dusty, warm, cool, rain, thunderstorm, good, etc. But these terms are not defined in an objectively-measurable way.

c. Road net mobility is characterized as unlimited cross-country movement, good road net, fair road net, poor road net, impassable terrain. But these terms are not defined in an objectively-measurable way.

d. Exceptional obstacles to advance is characterized as river, flooded area, fortified zone, exceptionally effective demolitions, urban area, sabotage by local populace, and desert. But these terms are not defined in an objectively-measurable way.

e. Situation on flanks is characterized (separately for left and right flanks) as comparable advance, faster advance, slower advance, flank threatened. But these terms are not defined in an objectively-measurable way.

f. Readiness condition is characterized as fresh, tired, weary, exhausted. But these terms are not defined in an objectively-measurable way.

g. Defender's posture is characterized as hasty defense, fortified defense, position defense, delay, withdrawal. But these terms are not defined in an objectively-measurable way.

7. Summary of Conclusions Regarding Advances:

a. (From pg. C-61) "Although no firm conclusions [regarding Operation C] can therefore be drawn [because Russian strength and hence force ratios could not be determined], the fluctuating rates of advance seem to be more directly related to the intensity of opposition and to natural obstacles than to the comparative size and strength of opposing forces."

b. (From pg. D-47) "The effect on rates of advance of major obstacles, even when not seriously defended, is clearly demonstrated on the matrix analysis charts [not reproduced here]. Fluctuations in rates of advance appear to be more significantly affected by obstacles and by intensity of hostile opposition than by force ratios. Weather appears to have little effect upon rates of advance where resistance is scattered and the road net is good. It seems possible to sustain tactical administrative march rates of 55-60 kilometers per day, despite necessary security measures to meet possible, though unexpected, opposition on the march and in bivouac. Major obstacles do not appear to affect tactical administrative road marches."

c. (From pg. E-42) "For the most part, low casualty rates and high advance rates are generally associated. Except possibly for the final week [of Operation E], fluctuating rates of advance seem to bear no relation to the opposing force ratios. In each of the three separate series of movements (between pauses) included in this operational period, rates of advance generally declined, following an initial surge. Although one major obstacle did not appear to affect the advance rate adversely (due principally to an exceptional effort which surprised the bridge defenders at Verdun), in general obstacles tended to reduce advance rates ... The armored division has generally higher rates of advance than the corps in each of the categories of the extent of intensity of opposition. This probably reflects the tactical employment of the armor with infantry as well as the ability to overcome opposition in moving situations."

d. (From pg. F-72, re: Operation F) "The rates of advance were the slightest in this sixth of the operations against the heavily defended border area of Germany. The cold, wet weather and resultant bad road conditions contributed to the corp's [reduced] mobility and slowed the potential rate of advance. Casualties were heaviest in this operation. Fluctuating rates of advance seem to have been more closely related to intensity of opposition, casualties, and environmental conditions than to force ratios."

e. (From pp. III-4 through III-7, the overall summary)

"(1) Rates of advance appear to be rather closely related to casualties sustained by the advancing force or to the intensity of combat as experienced by the attacker; the defender's casualties appear to have little or no close relation to the rate.

"(2) The following, in an approximate order of significance, appear from the operational summaries and the matrix analyses to be the operational considerations most affecting rates of advance:

"(a) The mission of the advancing force (as related to terrain objectives and the status of adjacent forces);

"(b) The missions and locations of adjacent [friendly] forces;

"(c) The mission of the defending force;

"(d) The relative combat effectiveness of the opposing force;

"(e) The intensity of the defending opposition as perceived by attackers.

"(3) It has proven impossible, within the time available for this study, to undertake a systematic assessment of the effects of logistical constraints upon rates of advance. ... the only firm conclusion possible from the data is the not surprising one that the advance rate falls rapidly to zero when fuel supply is interrupted.

"(4) The following, in approximate order of significance, appear to be the environmental considerations most affecting rates of advance:

"(a) Terrain configuration in general;

"(b) Weather;

"(c) Exceptional obstacles, such as rivers and urban areas;

"(d) Road net and road conditions (other than as affected by weather)"

"(7) In general, overall rates of advance (as well as rates against varying intensities of resistance) tend to be greatest in the first few days and to decline gradually but steadily over the period of the advance.

"(8) The analytical results of this study appear to indicate three major categories of advance under combat circumstances:

"(a) Category I, against determined opposition, when the defending force has sufficient capability and determination to attempt to stop or to limit severely the attacker's advance; the attacker's force superiority in such a situation is probably in the range of 1.1 to 1.3

"(b) Category II, against light opposition, when the defending force does not have the capability or the intent to interfere seriously with the advance, and limits its efforts to occasional delay and harassment; a force superiority of 1.3 or more is probably the threshold for this category.

"(c) Category III, an administrative move in which no substantial resistance is expected, but in which some opposition may be encountered from hostile air or ground forces. ...

"(10) The simple comparison of long distance rates of advance of World War II armies and Napoleon's pre-20th Century armies provides a basis for determining trends, which in turn may help to forecast the effects of modern means of transportation upon future rates of advance. Some preliminary comments, based upon the very limited data presented on the overall matrix analysis chart:

"(a) Modern means of transportation do not appear to have affected Category I rates of advance of modern armies, as compared with pre-20th Century armies;

"(b) Modern means of transportation in World War II, as compared with those of pre-20th Century armies, appear to have about doubled Category II rates of advance for periods of up to approximately one month; for longer periods the rates apparently decline rapidly to approach those of pre-20th Century armies;

"(c) Modern means of transportation in World War II appear to have approximately tripled Category III rates of advance in comparison to those of pre-20th Century armies for short periods of time."

f. (From pp. IV-1 through IV-3, Conclusions Section)

"General Conclusions ...

"2. It is likely that force ratios, however they may be calculated, do not influence rates of advance, but that sustained advances are probably not possible unless a threshold force ratio superiority has been achieved; more research with a larger data base will be necessary to confirm this tentative conclusion. ... "

"Specific Conclusions

"1. The following, in approximate order of significance, appear from the data available for this study to be the operational considerations most affecting rates of advance:

"(a) The mission of the advancing force (as related to terrain objectives and the status of adjacent forces;

"(b) The missions and locations of adjacent [friendly] forces;

"(c) The mission of the defending force;

"(d) The relative combat effectiveness of the opposing force;

"(e) The intensity of the defending opposition as perceived by attackers.

"2. On the basis of data analyzed in this study it is not possible to assess the significance of logistical constraints on the rate of advance.

"3. The following, in approximate order of significance, appear to be the environmental considerations most affecting rates of advance:

"(a) Terrain configuration in general;

"(b) Weather;

"(c) Exceptional obstacles, such as rivers and urban areas;

"(d) Road net and road conditions (other than as affected by weather).

"4. On the basis of an arbitrarily-established basis for normalizing variable factors, the data available in this study suggest the following as tentative range, and averages, of rates of advance against varying intensities of opposition:

"Category I—Advance against determined opposition"A. Against Intense Resistance:

Overall range: 1.32-4.04 km/day; average: 2.80 km/day

Corps range: 2.07-4.04 km/day; average: 2.76 km/day

Armd. Div. range: 1.32-3.88 km/day; average: 2.89 km/day

"B. Against Moderate Resistance:

Overall range: 4.18-15.87 km/day; average: 10.10 km/day

Corps range: 4.18-15.53 km/day; average: 9.48 km/day

Armd. Div. range: 7.63-15.87 km/day; average: 10.40 km/day

"Category II—Advance against light opposition"A. Against Slight Resistance:

Overall range: 5.15-36.72 km/day; average: 23.34 km/day

Corps range: 5.15-29.76 km/day; average: 20.79 km/day

Armd. Div. range: 13.67-36.72 km/day; average: 25.69 km/day

"B. Against Negligible Resistance:

Overall range: 34.55-78.22 km/day; average: 54.79 km/day

Corps range: 34.55-67.46 km/day; average: 48.66 km/day

Armd. Div. range: 44.50-78.22 km/day; average: 63.30 km/day

"Category III—Unopposed administrative combat march:

69.78 km/day, average;

45.60 km/day, corps rate;

120.06 km/day, armored division rate;

55.60 km/day, infantry division rate."

8. Comments and Critique:

a. The historical data assembled is impressively extensive. The narrative accounts of the actions studied are excellent.

b. The report states that "For Operations E and F [the force ratios, relative combat effectiveness, relative mobility effectiveness, and intensity of combat] have been calculated by the Quantified Judgment Method (QJM)." Use and interpretation of the data on Operations E and F should take this fact into account.

c. The characterizations of intensity of opposition and of road net mobility may be circular. For example, a judgment that the road net was inadequate may inadvertently be influenced as much or more by the perceived slow rate of advance as by the "inherent" characteristics of the road net. (For example, compare ORALFORE's conclusions with those in our summary SIMPKIN-1984.) Such vicious circles tend to crop up more often when characterizations are judgmental than when they are objectively measurable. The following may also be circular:

- (1) Exceptionally effective demolitions
- (2) Readiness condition (fresh, tired, etc.)
- (3) Defender's posture

d. It is clear that the weight of evidence strictly contained within this report is insufficient to sustain its conclusions. Hence they plainly are based partly on study participant's wide familiarity with military history in general as well as on the information in this specific study.

e. ORALFORE's conclusion 7d above asserts that rates of advance are influenced by intensity of opposition, casualties, and environmental conditions; but not by force ratios. If true, then it follows that intensity of opposition, casualties, and environmental conditions are not related to force ratios.

f. It seems inconsistent to assert that rates of advance are not much affected by force ratios, and then to assert, as in 7e(8) above, that the major "Categories" affecting advance rates are associated with certain critical force ratios.

g. The hypothesis that some threshold value of force ratio is necessary before advances are possible was put forth much earlier by Mulholland and Specht (see our summary RAND-1953).

RECORD-1973

1. Document:
 - a. Title: Armored Advance Rates: A Historical Inquiry
 - b. Author: Record, Jeffrey
 - c. Date: September 1973
 - d. Organization: Military Review, pp. 63-72
 - e. Number: September 1973
2. Objectives and Scope:
 - a. This article's purpose is to question the validity of Soviet General Staff Guidelines calling for sustained rates of advance of 70 miles per day.
 - b. Operations studied include:
 - (1) German XIX Corps from Border to Channel, May 1941
 - (2) German 2nd Panzer Group from start of the Barbarossa offensive to Smolensk, June 1941
 - (3) German Afrika Korps, advance to Mersa Matruh, June 1942
 - (4) British 8th Army, El Alamein Offensive, October 1942
 - (5) US Third Army from Avranches to Troyes, August 1944
 - (6) Israeli units in Six-Day War, June 1967
3. Using the Following Data Sources: Various history books
4. Distance Defined As: Unspecified
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As: Unspecified
7. Summary of Conclusions Regarding Advances:
 - a. (pg 70) "As is clear from our discussion so far, such a pace [as the Soviet postulations of sustained progress at a rate of 70 miles per day] would be historically unprecedented. No sizable armored formation operating in Europe during the Second World War maintained a rate of advance in excess of 35 miles per day. Although some individual units did register one-day gains of 50 and even 60 miles, these advances in every instance were virtually uncontested.
 "Only in the desert have tank formations recorded sustained advances of 70 miles per day or more, most of which were again facilitated by an absence of enemy resistance. The assumption that the USSR could, in a European environment, duplicate the respective feats of the Afrika Korps and the Israeli Army is completely unwarranted."

8. Comments and Critique:

a. This work was important in bringing a greater degree of tactical and historical realism to the debate on Soviet advance rates. It continues to serve as an admirable caution that many of the episodes billed as "lightning advances" were often not all that rapid, particularly when compared to the inherent speed of the individual vehicles.

b. However, the evidence presented is largely anecdotal and cannot serve as a basis for overgeneralization or overextrapolation.

WAINSTEIN-1973a

1. Document:

a. Title: Rates of Advance in Infantry Division Attacks in the Normandy-Northern France and Siegfried Line Campaigns

b. Author: Wainstein, Leonard

c. Date: December 1973

d. Organization: Institute for Defense Analyses

e. Number: Paper P-990, AD-779 882

2. Objectives and Scope:

a. (pg v, Preface) "The research presented in this paper is in the area of historical combat statistics for possible use as input to simulation models. ... The purpose of this paper is not to attempt to establish precise relationships among the factors of rate of advance, casualties, resistance, and terrain. There is usually insufficient numerical data for that even on a one-sided basis. Rather it is hoped that some general relationships—some proportions—will emerge that will be of use to model-builders."

b. The operations studied consist of 90 attacks in which an advance of at least 300 yards was gained by allied infantry divisions in NW Europe during WWII. Of these, 50 occurred in the Normandy-Northern France area between mid-June and mid-August 1944 (save for two during the capture of Cherbourg in early September), 35 are from the American attack on the Siegfried Line between 11 September and 16 December 1944, and 5 are from the final US counterattack phase of the Ardennes campaign (January of 1945). Eighty-seven of these attacks were made by US units, and 3 by Canadian divisions.

c. (pg 1) "It should be stressed that many attacks fail to gain any ground, and these 90 advances were chosen because they did show an advance. Later, the approximate percent of all attacks in which advances occurred is determined." (pg 15) "... I have arbitrarily considered that advances of under 300 yards represented no advance."

3. Using the Following Data Sources:

a. Official US Army histories and available archival records such as Daily Summaries, SitReps, G1 Journals, etc.

4. Distance Defined As: Unspecified, but presumably FEBA displacement.

5. Time Interval Defined As: (pg 10) "For simplicity's sake, a single day has been established as the base unit, despite the fact that in nearly every case the action lasted less than a full day and, for most actions, even less than the daylight period of the day. The purpose of the study is not to determine rates of advance on an hourly basis, but rather to determine the scale of the forward movement achieved in a good-sized sample."

6. Situational Descriptors Defined As:

a. (pg 1) "Only bald statistics are presented, since, for purposes of statistical analysis and simulation, descriptive text on each battle really contributes little beyond some additional understanding of factors that cannot be quantified."

b. (pg 5) "Terrain has been categorized as (1) open, (2) mixed, and (3) close or difficult. The word mixed thus includes the two commonly used descriptors, moderately open and moderately close, the distinction between which is really rather fine and essentially judgmental." (pg 8) "... it is generally not possible to distinguish what proportion of an action occurred in a town versus the proportion that occurred on the open ground around it."

c. (pp 8-9, *passim*) "In the absence of German strength figures comparable to those obtainable for US units, degree of resistance rather than force ratio or enemy posture has been used as the descriptor for the enemy. ... The degree of enemy entrenchment—fortified position, prepared position, etc.—is not the best descriptor, since it is the fighting spirit of resistance maintained by the troops, as much as the strength of their position, that ultimately determines degree of resistance. ... In the Normandy cases, three simple categories of resistance are used: heavy, moderate, and light. For the Siegfried Line cases, five categories are used because the records employed a further breakdown of descriptor: heavy, moderate to heavy, moderate, light to moderate, and light. ... The descriptor terms are those generally used in reference to the actions in the official histories. Yet in several cases the term used does not appear to accord with the casualties suffered. ... It is obvious that no standard measure exists for the relationship between degree of resistance and casualties ..."

d. (pg 10) "While the actions listed all involved a single division, it should be understood that the entire division was not always involved. Attacks involving two or three regiments were most common, while single regiment attacks are also included, since they did represent an effort mounted by a division in which the division artillery and tank units invariably participated. There are also included cases where all three regiments or brigades attacked simultaneously, but divisional attacks using only a portion of the division were the norm. Battle really was a contest between regimental-sized units with their supporting elements."

7. Summary of Conclusions Regarding Advances:

a. (pg 15) Based on "a hasty search," for the Normandy-Northern France area, 40 out of 371 division attack days showed "no" advance (i.e., advances of less than 300 yards). (pg 20) For the Siegfried Line area, 17 out of 137 division attack days showed "no" advance.

b. (pg 21) "The variations (in Tables 4 and 8) relating terrain type to degree of resistance are so marked that any average [relating rate of advance to degree of resistance] is highly questionable." Apparently Wainstein is here referring to the marked tendency for "heavy" resistance and "close" terrain to occur together. The combined cross-tabulation for all the data in this report is as follows, where we have collapsed the Siegfried Line resistance categories to three:

Terrain Class	Degree of Resistance			Total
	Heavy	Moderate	Light	
Open	4	0	9	13
Mixed	13	17	14	44
Close	22	3	3	33
Total	39	25	26	90

8. Comments and Critique:

a. This paper is very clear and precise in its description of what was done and what was not done. Its findings and conclusions are carefully framed to avoid overgeneralizing and overextrapolating from the data actually presented. As a result, its conclusions are clearly supported by the evidence presented.

b. The limitation to advances of 300 yards or more is arbitrary and unfortunate. Also, it would have been better had Wainstein provided in his data tabulations at least a general description of the portion of the division actually participating in the attacks.

c. The association between degree of resistance and terrain reinforces the suspicion that there is a pervasive systematic connection here—possibly due to the defender's tendency whenever possible to select "close/difficult" terrain for his most determined stands. An alternative is to postulate that attackers tend to perceive the terrain as "close" when resistance is heavy, i.e., that the association is caused by the vicious circle alluded to elsewhere. It is hard to find solid evidence for or against the suspected vicious circle.

WAINSTEIN-1973b

1. Document:

- a. Title: An Examination of the Parsons and Hulse Papers on Rates of Advance
- b. Author: Wainstein, Leonard
- c. Date: December 1973
- d. Organization: Institute for Defense Analyses
- e. Number: Paper P-991, AD-779 848

2. Objectives and Scope:

a. (pp v-vii, Preface) "The motivation of the research treated in this paper was the thought that a critique of the Parsons and Hulse papers, in order to present for general use an analysis of their content and character, might be of utility to the wargaming community at large. The prime purpose was to examine their sources to see how well they supported the papers. It was not intended to check their claimed sources against other sources. ... It was the intention of this analysis to determine how faithfully and to what degree the Parsons-Hulse papers reflected the historical record they claimed to have used."

b. The operations studied are the same as those in the papers by Parsons and Hulse (see our summaries HULSE-1954 and PARSONS-1954).

3. Using the Following Data Sources:

- a. Hulse, COL Allen D., "Movement." Staff Memorandum SM-22-CORG. Combat Operations Research Group. 9 August 1954
- b. Parsons, LTC Norman W., "Military Unit Rates of Advance in Attack." Staff Memorandum SM-29-CORG. Combat Operations Research Group. 14 September 1954
- c. And the sources cited by the above

4. Distance Defined As: As in the sources used.

5. Time Interval Defined As: As in the sources used.

6. Situational Descriptors Defined As: As in the sources used.

7. Summary of Conclusions Regarding Advances (pp 15-16, *passim*):

a. "These seminal papers were rough, hasty efforts, inputs to a study, not careful pieces of research adequate for broad applicability. Both authors viewed their papers as tentative and recommended further research on which to base their findings more soundly."

b. "The numerous specified and unspecified qualifications surrounding the data have been overlooked in the transformations of the originals."

c. "The wide variation among the sizes of the sample units examined in both papers makes questionable their generalized findings."

d. "Only part of Parsons' data is historically verifiable. A large proportion of data is his personal judgment, not historical fact drawn from sources. This is especially important in regard to his data categories of enemy strength and degree of resistance. He had numerical enemy strength in only 6 (of 24) examples, and US strength in no case. Enemy resistance descriptors were drawn from the sources in only 14 of 24 examples. ... In the six examples mentioned above, one had no resistance descriptor

from sources. Thus, Parsons has only five historically verifiable examples as a basis for his generalizations in regard to force ratio, degree of resistance, and advance."

e. "Hulse has only two cases where he describes specific enemy strength as a basis for similar generalization. He, too, apparently relied heavily upon his own judgment."

f. "Perhaps the best that can be said is that these two papers represent only a hasty impressionistic view of the subject of rates of advance."

8. Comments and Critique:

a. Wainstein's critique of the Hulse and Parsons papers is just, but it should be balanced with a recognition that they substantially improved upon the methods previously used in US Army wargames.

b. Mader's paper (see our summary MADER-1971) traced the evolution of rates of advance used in wargames forward in time from the Hulse and Parsons papers. Here Wainstein traces backward in time to the sources cited by Hulse and Parsons.

BARRIER-1974

1. Document:

- a. Title: Historical Evaluation of Barrier Effectiveness
- b. Author: HERO
- c. Date: March 1974
- d. Organization: Historical Evaluation and Research Organization
- e. Number: AD-A050 781

2. Objectives and Scope:

a. (pg 1, Introduction) "HERO has undertaken a study of the uses and effects of obstacles in modern and future combat in Europe as a preliminary but substantive effort which it was expected would (a) provide sufficient specific data to permit tentative development of quantitative inputs for combat models with respect to efforts to create or improve obstacles and barriers, and to their effectiveness under varying circumstances of combat, as well as planning factors for preparation or improvement of obstacles and for obstacle effects both individually and in barriers, and (b) provide a basis for refinement of such inputs and factors through subsequent development of an expanded data base."

b. The operations studied were:

- (1) German attack on the southern (Voronezh Army Group) flank of the Kursk salient
- (2) Nikopol bridgehead (defense of by Germans)
- (3) Il Goglio Pass (defense of by Germans)
- (4) Battle of the Bulge (US opposition to German advance)

3. Using the Following Data Sources: Various Soviet and other sources

4. Distance Defined As: Unspecified, but presumably the displacement of the FEBA. Most of the values are characterized as "Average Distance Advanced," or similar phrases.

5. Time Interval Defined As: Unspecified

6. Situational Descriptors Defined As: Unspecified

7. Summary of Conclusions Regarding Advances (pp 184-186. *passim*):

a. "It is impossible to relate the defensive or delay effect of natural or artificial obstacles directly to force ratios, in terms of either numerical strengths or firepower scores. These ratios have little meaning unless they are modified to reflect the effects of environmental and operational variables of combat upon the opposing forces."

b. "Obstacles and barriers seem to have made an important contribution to defensive combat indirectly through the delays and exposure to firepower imposed on the hostile force."

8. Comments and Critique:

a. The descriptions of the historical barriers and of the actions surrounding them are extensive and helpful.

b. Nevertheless, four episodes are a slender basis for broad claims and sweeping conclusions. Those in the report appear to be somewhat overgeneralized and overextrapolated for the data actually provided in the report, although they no doubt were also informed by the broad familiarity of study participants with military history in general.

RMC-1974

1. Document:

- a. Title: Research Study on Predictive War Game Factors: Final Report
- b. Author: Cockrell, James K., and Donn Carter
- c. Date: March 1974
- d. Organization: RMC Research Corporation
- e. Number: Prepared for SHAPE Technical Centre, Contract C.72-03

2. Objectives and Scope:

a. (pg 1, Introduction) "The purpose of the effort was to produce data and algorithms that can be used in SHAPE computer war games to predict the outcome of engagements between ground units in non-nuclear war situations. Outcome measures were to be distance advanced and primary resource attrition suffered in 24-hour periods."

b. The operations studied consisted of:

(1) One set of 150 attack days by forces of brigade to division size against defenses in place (as opposed to delaying actions) during the first 18 days (16 December 1944 to 2 January 1945) of the Ardennes campaign of WWII (Battle of the Bulge), and

(2) A second set of 100 attack days from the Lorraine campaign that occurred between 8 September and 27 November 1944 in eastern France.

3. Using the Following Data Sources:

a. (pg 7) "The US National Archives Captured Records Center was the primary source for German unit records and other documents. These included microfilmed copies of unit operational records, war maps, and results of interviews or responses from captured German division, corps, and army commanders and staff officers. ... For US battle day information the primary source was the National Records Center of the Archives. After action reports, daily and other periodic reports, journal files, histories, and order of battle studies from Army level down to battalion level were examined to establish the composition, location, disposition, mission and activity of the units of interest."

b. (pg B-2) "Attack missions were coded as obtained from recorded mission statements. *Limited objective attacks or counterattacks which were considered to have been limited by mission considerations rather than by resources were not included in the sample* (emphasis added). For example, an attack clearly conducted to restore the front line would not be included. Also left out were any reported attacks where there appeared to be significant question as to whether an attack was really made." (pg 6) "... it was important to avoid 'pseudo attacks' and delaying actions in which the results of a day's actions were dictated by considerations other than an attack mission opposed by a defense mission."

4. Distance Defined As: (pg B-5) "Advances were measured to within 100 meters from the line occupied by the defense when the day's fighting began—that is, only penetration distance was counted, not advance-to-the-assault-position distance." (pp 67-68) "Many days in which there were division attacks during this period [Lorraine Campaign] could not be included in the data set because there was insufficient data on either the German or the US force, or there was evidence that a German defending force

had withdrawn rather than attempting to defend its positions against a US attack. (Whenever an attack struck a defended position to which the defender had withdrawn, the ensuing battle was recorded from that point on, as if the attack had begun at that point—as long as this did not occur toward the end of a day of attacker movement, because it was observed that in such cases the attack was usually not continued long after dark.)”

5. Time Interval Defined As: (pg 6) “These [data collection and other considerations] combined to indicate a nominal 24-hour period and a nominal division level on the attack force side as natural separation points.”

6. Situational Descriptors Defined As:

a. The tabulated data include the sector of the front, the date, the number of infantry platoon equivalents, tank strength, antitank firepower, artillery firepower, personnel casualties, tank and tank-equivalent losses, visibility, mobility, attacker and defender posture, and the distance advanced. The technical definitions and detailed codes used to describe all these items are too complex to summarize readily. See the RMC report for details.

b. The listing of the Lorraine data set is identical in format and content to that of the Ardennes data set. Some of the Lorraine data columns are not complete because the results of the regressions [done on the Ardennes data set] indicated that some data items would not be used in the test of the Lorraine data set. At this point in RMC's study, available resources would not support any additional work beyond the minimum necessary to complete the effort. The vision-range coding did not attempt to discriminate between the 2 and 3 codes (100-300 meters and 300-700 meters) because this degree of detail would not be recognized in the dummy coding used and it was hard to get from map data.

7. Summary of Conclusions Regarding Advances:

a. (Figures 4 and 5, pp. 50-51) The predictive equation for advance distances, based on the Ardennes data set, is as follows:

Advance distance (km in one day) = 0.939 plus the following 25 terms:

$$\begin{aligned}
 &+0.374(A \text{ Inf Pltns} - 6.366) \\
 &-0.408(D \text{ Inf Pltns} - 4.543) \\
 &+0.061(A \text{ Tanks} - 11.564) \\
 &-0.154(D \text{ Antitank} - 7.137) \\
 &+0.063(A \text{ Arty} - 4.153) \\
 &-1.561(D \text{ Arty} - 2.449) \\
 &+0.543(A \text{ percent Inf Mechanized} - 4.533) \\
 &+1.949(\text{Defense Preparations}^a) \\
 &-0.296(\text{Visibility}^a) \\
 &+0.142(\text{Mobility}^a) \\
 &-0.071(A \text{ Inf Pltns} - 6.366)^2/2 \\
 &+0.022(D \text{ Inf Pltns} - 4.543)^2/2 \\
 &-0.005(A \text{ Tanks} - 11.564)^2/2
 \end{aligned}$$

$$\begin{aligned}
&+0.007(D \text{ Antitank} - 7.137)^2/2 \\
&-0.032(A \text{ Arty} - 4.153)^2/2 \\
&+0.247(D \text{ Arty} - 2.449)^2/2 \\
&+0.029(A \text{ Inf Pltns} - 6.366)(D \text{ Inf Pltns} - 4.543) \\
&-0.010(A \text{ Inf Pltns} - 6.366)(A \text{ Tanks} - 11.564) \\
&+0.015(A \text{ Tanks} - 11.564)(D \text{ Antitank} - 7.137) \\
&+0.025(D \text{ Inf Pltns} - 4.543)(D \text{ Antitank} - 7.137) \\
&+0.074(D \text{ Arty} - 2.449)(A \text{ Inf Pltns} - 6.366) \\
&-0.168(D \text{ Arty} - 2.449)(A \text{ Tanks} - 11.564) \\
&+0.189(D \text{ Arty} - 2.449)(\text{Visibility}^a) \\
&+1.843(\text{German Attack}^a) \\
&+\text{NormRanVar}(0, 3.16)
\end{aligned}$$

where

A = Attacker

D = Defender

Inf Pltns = Infantry platoons per km of front

Tanks = Tanks per km of front

Arty = Close support artillery rounds fired per 100-km of front

Antitank = Defending antitank fire units per km of front

Defense Preparations^a = 0 for prepared defense, 1 for unprepared defense

Visibility^a = 0 if long vision range is ≤ 700 meters, 1 if over 700 meters

Mobility^a = 0 if tank mobility beyond the defensive position is limited, 1 if not

German Attack^a = 0 if US is attacking, 1 if Germans are attacking

NormRanVar(μ, σ) = A normal random variable with mean μ and standard deviation σ

b. (pg 52) "The impacts of the square terms (e.g., Attacker Infantry times Attacker Infantry) can be inferred from a comparison of the signs of these impact coefficients with those of the basic or linear coefficients for the same variables. In all cases, the signs are opposite." So diminishing returns sets in, and eventually increases in a particular factor even cause the advance rate to decrease (provided of course that all other independent variables are held fixed). Analogous remarks apply to the cross-product terms, although the situation here is much more complex, with some terms reflecting increasing returns to scale.

c. (pg 55-56) "The prediction equation [shown above] should only be used to predict advance distances on battle days of the types included in the data sample and described in Chapter 2. ... Two conditions must be observed: the density figures that are entered must represent troops actually available for the battle concerned, and should exclude troops on flank security missions or in sectors not included in the attack; and there must be a true defense, not a withdrawal. A mission to "execute maximum delay in zone" could be considered as equivalent to a defense, but a phased (time-scheduled) delay should usually be considered more like a withdrawal.

"Using the predictive equation requires one decision of a policy nature: what use is to be made of the German Attack code coefficient? Its value is simply the average difference between advances in attacks by US troops and those by German troops, at equal values of all [other] variables. Thus, if one considers that the US data are more

likely to represent the case he wishes to predict he should exclude that coefficient. Other alternatives are to include it and [yet another alternative is] to use an average value."

d. (pg 56) Use of the equation also requires replacing the linear weighting values used by RMC to compute antitank firepower scores for mixes of WWII antitank weapons with new values appropriate to the modern weapons and targets (tanks) that are to be represented.

8. Comments and Critique:

a. This study represents a major effort to assemble a substantial data base, and to apply powerful multivariate statistical analysis methods to extract from it solid, historically-based relationships that could be used to model attrition and advance rates in wargames and simulations.

b. It could be argued that not only must the antitank weighting factors be updated, but that nearly *all* the input values should be updated as well. This includes specifically the infantry platoon counts, percent infantry mechanization, visibility conditions, number of tanks, artillery rounds, and mobility. There is no adequately convincing empirical evidence on either side of this issue.

c. (pg 69) "The terrain analysis for the Lorraine data set was made without the benefit of a terrain reconnaissance and is not considered to be as accurate as is that used in the Ardennes data sample."

d. (pp 70-80) The Lorraine data were also used to generate a predictive equation for advance distances. When this was done, it was found that "... the signs of two of the basic [regression] coefficients ... are different from those for the Ardennes sample and are counter-intuitive; the [regression] coefficient for attacking tanks is negative and that for defending antitank firepower is positive. ... The value of the standard battle advance [i.e., the constant term for a regression centered at the means or nominal levels of the independent variables] is 1.75 km compared with 0.94 km for the Ardennes set. ... These differences ... could imply that the two sets are different in the sense that [their regression equations differ to a statistically significant degree] ... The test [for such differences between the regression equations] showed that with 99 percent confidence the [regression] coefficients from the two data sets are different. ... [Because this result could arise from errors in either or both data sets] the results of the testing of the Ardennes-derived predictive equation for advance distance by using the Lorraine data set are inconclusive. ... There is a need for further work with the Lorraine set and further regression work with both sets separately and pooled. ... It is also desirable to experiment further with resource variable formulation." The so-called "predictive" equations are actually merely "fitted" equations. Their interpretation as "predictions" depends upon the user's volition.

e. (pg 73) "The indication that the [Lorraine] data set is not taken from the same population as the Ardennes set may be the result of data errors. It was found during the long series of regressions using the Ardennes set that data errors are difficult to identify and that the best indicator of error is peculiar behavior of regression results—analysis of these then leads back to particular elements of the data and rigorous reexamination then frequently exposes errors. It was not possible to perform any such analyses on the [Lorraine] data set because of contract fund limitations, and it is likely that at least some of the difference between the two sets is due to the [Lorraine] data set not having been "shaken down". However, this process could also focus attention on errors in the "non-fitting" data values to the exclusion of errors in the "fitting" data—a focus on Type I errors to the neglect of Type II errors. Such shake-downs could exacerbate the "over-fitting" or "data-dredging" problems mentioned by Lindley. (See the important

review of this document made by Prof. Lindley summarized in LINDLEY1976. The papers by D. A. Freedman and by L. S. Freedman and D. Pee are also relevant—bibliographic citations to these are given in paragraph 8b of our summary LINDLEY-1976. See also Schäffer's alternative analysis of the Ardennes data summarized in SCHÄFFER:1977)

f. Some portion of the attacks were night attacks (cf. pg. 16 and pg. 20), but this information has not explicitly been recorded in the RMC report. The effect of night on visibility are included in the Visibility codes, but they also include the effects of many other visibility-degrading conditions. The Germans conducted night attacks substantially more frequently than did the US. Hence, the visibility conditions are statistically confounded with the side attacking.

g. The general character of the Lorraine and Ardennes campaigns differs in three principal ways.

(1) In the Lorraine campaign troops were less concentrated on both sides, resulting in more isolated battles rather than in linear front action.

(2) Water courses in the Lorraine area at the time were flooded and limited the movement of tanks to captured or erected bridges. Infantry were less restricted. In the Ardennes, tank movement was significantly less restricted most of the time.

(3) The Lorraine data set has a higher percentage of brigade-size attack forces than the Ardennes data set.

h. As noted under 4 (definition of distance) above, the data are for advances that are actively and determinedly opposed, and do not include unopposed advances.

FEBA-1975

1. Document:
 - a. Title: FEBA Movement and Attrition Processes
 - b. Author: War Gaming Directorate
 - c. Date: 21 February 1975
 - d. Organization: US Army Concepts Analysis Agency
 - e. Number: CAA-SP-75-1
2. Objectives and Scope:
 - a. (pg 1, Summary) "The US Army Concepts Analysis Agency undertook this study to see if a new approach could be found to examine the battle process and to estimate FEBA movement and force attrition. The investigation tested selected multivariate analysis techniques, which have not previously been applied to the battle process or to predicting battle outcomes."
 - b. The operations studied consisted of 60 WWII battles in Italy.
3. Using the Following Data Sources: The same 60 battles were included in Pearsall's paper, and derive from HERO's earlier papers. See our summary PEARSALL-1972.
4. Distance Defined As: Not specified
5. Time Interval Defined As: Not specified
6. Situational Descriptors Defined As: Some 40 different independent variables were defined and used. These include variables related to the combatant's strengths in personnel, machineguns, mortars, antiaircraft weapons, artillery, armor and other motor vehicles, and air support; environmental descriptors for the weather, terrain, season of the year; and descriptors of the type of attack (general attack, counterattack, holding attack, and pursuit). In addition, eight dependent variables were defined and used, including the distance and rate of advance, casualty levels and rates on both sides, battle duration, and the ratio of attacker to defender casualties.
7. Summary of Conclusions Regarding Advances:
 - a. The principal independent variables used were:
 - (1) Force ratio (attacker to defender)
 - (2) Motor vehicle ratio (ratio=attacker's motor vehicles divided by defender's motor vehicles)
 - (3) Attacker's antipersonnel weapons per unit defender strength
 - (4) Defender's antipersonnel weapons per unit attacker strength
 - (5) Attacker's mortars per target (target=the sum of defending machineguns, mortars, and antitank weapons)
 - (6) Defender's mortars per target
 - (7) Attacker's artillery per target (target=the sum of defending machineguns, mortars, antiaircraft weapons, antitank weapons, and artillery weapons)
 - (8) Defender's artillery per target
 - (9) Attacker's aircraft per ground target (target=the sum of defending machineguns, mortars, antiaircraft weapons, antitank weapons, artillery weapons, and armor vehicles)
 - (10) Defending aircraft per ground target
 - (11) Attacker's antivehicular weapons per target ratio (ratio=the sum of

attacker's antitank weapons, artillery weapons, armor vehicles, and air sorties divided by the defender's motor vehicles)

- (12) Defender's antivehicular weapons per target
- (13) Attacker's aircraft to antiair index (index=attacker's sorties divided by the sum of defender's antiaircraft weapons and sorties)
- (14) Defender's aircraft to antiair index
- (15) Attacker's tanks to antitank index (index=attacker's armor vehicles divided by the sum of defender's antitank weapons and armor vehicles)
- (16) Defender's tanks to antitank index.

b. The principal dependent variables used were:

- (1) Attacker's advance rate in miles per day
- (2) Attacker's casualty rate (percent per day)
- (3) Defender's casualty rate (percent per day)
- (4) Casualty ratio (attacker to defender)

c. (pg 7) "A long standing assumption among military gamers, analysts, and planners is that there is a functional relationship between the rate of advance of an opposed attacking force and the combat power of each force, as constrained or enhanced by environmental conditions present on the battlefield. This hypothesis is intuitively acceptable to most interested personnel, since it seems to reflect the application of established physical laws associated with force and movement of mass. Applied as early [as] 1954 [apparently a reference to the Hulse and Parsons papers], this hypothesis remains one of the primary bases for generating FEBA movement in current war game/simulations methodology."

d. (pg 13) "Ten factors dominate the battlefield process. These are, in order of importance:

- (1) Defender's close air support
- (2) Attacker's combat strength
- (3) Defender's relative weakness
- (4) Attacker's close air support
- (5) Battle intensity
- (6) Attacker's air superiority
- (7) Defender's relative mobility
- (8) Attacker's tank strength
- (9) Defender's preparedness
- (10) Attacker's relative attrition."

e. (pg 13) "Strength ratio has a significant influence on FEBA movement and casualty rates."

f. (pg 13) "Weather, season and terrain exert limited influence on FEBA movement and casualty rates."

g. (pg 13) "Defense posture (defense preparedness) exercises significant influence on FEBA movement and the defender's casualty rates."

h. (pg 13) "The type of attack impacts significantly on the defender's casualty rate."

i. (pg 13) "Relative mobility significantly influences FEBA movement and casualty rates."

j. (pg IV-22) [If I'm interpreting the paper correctly] the proposed equation for FEBA movement rate in miles per day is:

$$\begin{aligned} \text{MIPD} = & -4.76(\text{DEF MG}) + 4.52(\text{DEF ARTY}) - 4.37(\text{DEF STR}) + \\ & 4.04(\text{ATK STR}) - 2.60(\text{DEF ARTY/TGT}) - 2.59(\text{DEF AVW/TGT}) + \\ & 2.55(\text{ATK ARMOR}) - 2.48(\text{ATK MG}) \end{aligned}$$

8. Comments and Critique:

a. This study is an interesting experiment in applying advanced and computationally demanding multivariate statistical techniques to help analyze a complicated data set. The multivariate statistical techniques included factor analysis, numerical taxonomy (or cluster analysis), multiple regression, and canonical correlation.

b. The study used factor analysis, followed by cluster analysis, followed by canonical correlation. The degree of "data dredging" and overfitting is disturbing. Page II-5 revealingly, if somewhat boastfully, remarks that "A total of 40 independent and 8 dependent variables were applied through the production phase of the project." The criticisms of this sort of procedure made by Prof. Lindley (see our summary LINDLEY-1976 and the Freedman articles cited in its paragraph 8b) are very pertinent.

c. The battle data in this report do not always agree with those used in the other reports summarized in MEFORD-1971 and PEARSALL-1972.

d. It is often difficult to determine just what procedures were applied, what results were obtained from them, and how those results were then interpreted to reach the conclusions given in the report. The staff paper fails to give crisply the most important results in a fashion that is readily comprehensible. It shows several graphs purporting to show good agreement between predicted and actual values, but is vague on how the "predicted" values were actually obtained. It results need to be interpreted with caution, since with 40 independent variables and only 60 data points, a good-looking fit is to be expected even if all the data are purely random.

MURPHY-1975

1. Document:

- a. Title: Opposed Movement Rates: A Staff Paper
- b. Author: Murphy, COL Joseph B., et al.
- c. Date: 15 May 1975
- d. Organization: US Army Concepts Analysis Agency, War Gaming Department
- e. Number: Unpublished

2. Objectives and Scope:

a. (pg v, Foreword) "The purpose of this paper is to provide the user with an unclassified easy to use reference document on the historical origin and development of movement rates. It is not an attempt to develop a universally-acceptable law of average opposed rates of movement."

b. No new historical research is contained in this report. All of its data were extracted from other reports on rates of advance.

3. Using the Following Data Sources: The Hulse and Parsons papers, and several wargaming manuals including those of USCONARC, Army War College, Research Analysis Corporation, US Army Concepts Analysis Agency, etc.

4. Distance Defined As: Unspecified, but presumably displacement of the FEBA.

5. Time Interval Defined As: Unspecified.

6. Situational Descriptors Defined As: Same as in the works consulted by this staff paper.

7. Summary of Conclusions Regarding Advances:

a. (pg II-5) "A review of the evidence presented in the referenced documents clearly suggests that a near-time formulation of a universally-applicable and acceptable law of average opposed movement rates is not feasible. Moreover, such a standard law is probably not even desirable. Historical analysis suggests that rates of advance should more appropriately be considered as part of a sensitivity analysis rather than precise, rigorous, self-sufficient study inputs."

b. (pg II-6) "The opposed movement rates used in most war gaming studies have a tenuous foundation in history. ... This paper ... is written to provide the user with an unclassified basic source document on opposed rates of movement."

8. Comments and Critique:

a. This paper is a convenient summary of several other documents. However, it contains only a few real historical data values. Most of the values in it are examples of those in use by various wargaming and analysis agencies.

QUICK WINS-1975

1. Document:

- a. Title: A Survey of "Quick Wins" in Modern War
- b. Author: HERO
- c. Date: October 1975
- d. Organization: Historical Evaluation and Research Organization
- e. Number: AD-A025 893

2. Objectives and Scope:

a. (pg 1, Introduction) "In an attempt to identify the factors which seem to have contributed to, or militated against, rapid and decisive victory, the Historical Evaluation and Research Organization (HERO) has studied seven examples of "quick wins" in modern war, three examples of "almost quick wins" and three examples that ended in stalemate."

b. The operations studied were Marengo, Ulm, Jena, Friedland, Danube, Russia, Lutzen-Bautzen, Vicksburg, Savannah-Raleigh, Appomattox, Sadowa, Metz-Sedan, Marne, Caparetto, Third Gaza, Megiddo, Flanders, Barbarossa, Malaya, Luzon I, Caucasus, Cobra, Luzon II, Manchuria, N. Korean Offensive, UN Offensive, Sinai Campaign, Samaria, and Golan.

3. Using the Following Data Sources:

a. (pg 2) "Only secondary sources are used because time did not permit consulting primary documents. Consequently statistical data is incomplete and may, in some instances, be questionable." Nevertheless, the report contains many tabulations and charts, and includes a chapter entitled "Quantitative Analysis." So apparently the authors believed their values sufficiently trustworthy to report them in quantitative form.

4. Distance Defined As: (pg 20) "[After preparing the narrative accounts] distances advanced during the campaign, or during the critical period of the campaign, were then determined for selected units (or as an average of the force as a whole, whichever seemed most reasonable and was facilitated by the availability of suitable data and maps)." What defines the duration of the campaign—or of its "critical period" are unspecified. Tabulated values are characterized as "Total Distance Considered," which in three cases (Russia, Barbarossa, and Malaya) differs from other values characterized as "Total Distance in Campaign." No indication is given as to whether the distance is "for selected units" or is instead "an average of the force as a whole."

5. Time Interval Defined As: Unspecified, but characterized as "Days in Campaign," or as "Days to Decision." For 21 of the 30 operations, these time intervals coincide, and in nine they differ. In six of the nine instances where they differ rates are based on the days to decision, but in three instances rates are based on the days in campaign. There is no discussion or explanation of these differences.

6. Situational Descriptors Defined As:

a. Several situational descriptors are used (e.g., "weapons quality," "political involvement," "simplicity," etc.) but are not clearly defined.

7. Summary of Conclusions Regarding Advances:

a. The conclusions (pp 21-22) do not address advances specifically. However, they do include the statement that "Although the sample of operations studied is not large, the analysis and the preceding conclusions show a consistency of conditions that point to some specific conclusions about factors of particular importance in attempting to gain a quick victory:

- (1) Planning. ...
- (2) Surprise. ...
- (3) Leadership. ...
- (4) Mobility. ...
- (5) Logistics. ...
- (6) Preponderance of Effective Force Strength. A disadvantage or only slight advantage in actual numbers of men and weapons can be overcome by the way in which they are used. ..."

8. Comments and Critique:

a. The narrative accounts of the actions are very good, and describe in some detail the operations considered.

b. It is not easy to tell just what the authors mean by many of their descriptors, such as "preponderance of effective force strength." Also, it is hard to judge the extent to which the values assigned to these descriptors are *post hoc*, and hence are affected by the vicious circle referred to elsewhere. The key question is whether those values were or could have been foretold before the campaign was conducted, rather than being based on after-the-fact knowledge of the campaign's results. Leadership and planning are prime examples. If the campaign turns out badly for side A, that is generally considered strong evidence that side A's planning and/or leadership were faulty. But evidently *before* the campaign was conducted, side A considered its planning and leadership to be adequate—for otherwise it would have changed them. Other examples could be cited, but the point is clear.

c. In several cases the time intervals presented in this document's Figure 5 (which is a table giving, among other things, the dates, time intervals, distances, and rates of advance for the operations studied) do not agree with the starting and ending dates given in the same table. Rates calculated by assuming the distances and the start-end dates to be accurate do not agree with the tabulated rate values.

d. See also our summaries BREAKTHRU-1976 and FALLACY-1977 for comparison. See the Wainstein paper summarized in our WAINSTEIN-1984 for an informative commentary on the WW II Soviet Manchurian campaign.

LINDLEY-1976

1. Document:

- a. Title: Predictive Relationships for Opposed Movement and Casualty Rates for Land Forces: A Feasibility Study
- b. Author: Lindley, Dennis V. and A. M. Skene
- c. Date: 23 January 1976
- d. Organization: University College, London
- e. Number: Unpublished

2. Objectives and Scope:

a. This document was prepared as a technical review of the analysis done in the RMC report (see RMC-1974) on the Ardennes and Lorraine data sets.

b. This report contains no new historical data, but it does provide a careful reconsideration of the statistical and other analysis methods used in the RMC report.

3. Using the Following Data Sources: RMC, James K. Cockrell and Donn Carter, "Research Study on Predictive War Game Factors," RMC Research Corporation, 7910 Woodmont Ave, Bethesda, MD 20814, March 1974 (Contract C.72-03 with SHAPE Technical Centre)—see our summary RMC-1974

4. Distance Defined As: Same as in the RMC document

5. Time Interval Defined As: Same as in the RMC document

6. Situational Descriptors Defined As: Same as in the RMC document

7. Summary of Conclusions Regarding Advances:

a. (pg 3-4, *passim*) "As a result the multiple regression had 45 [freely adjustable] parameters in it ... there are 150 data points. ... Significance tests were performed [in the RMC report] (though only at 50 percent level) ... and many effects were found to be zero. Nevertheless we feel that the danger of overfitting is serious and that the resulting equations are unlikely to be reproducible."

b. (pg 5) "Perhaps the most important result to be extracted is that there is an apparently large part of the variability in the advance distance that seems difficult to explain in terms of any of the other variables upon which data are available [in the RMC report]. This feature will occur repeatedly in our analyses."

c. (pg 9) "Some part of our time was spent on trying to devise a mathematical model that might be tested against the data, somewhat on the lines of Lanchester's. We were unsuccessful in this but nevertheless feel that this is a promising line of development that ought not to be neglected."

d. (pp 31-35, *passim*) "The investigations in this pilot study have confirmed the ideas of earlier analyses that the following factors can have an influence on the distance an attacker advances:

- (1) Defence posture
- (2) Some measure of relative strengths, including mechanization
- (3) Battle mode: whether US or German and whether accompanied by a counterattack or not,

but that the remaining variables seem to have little if any effect. ... [These findings are

based on ignoring the data on actions with zero advance distances or with counterattacks.] The introduction of [actions with] zero advance distances and counterattacks reduces the explanatory power of these variables. In general most of the models seem to account for around 50 percent of the variability observed. ... it seems unlikely that the data [in the RMC report] could explain the differences between the three main groups: German Ardennes attacks; US Ardennes attacks; US Lorraine attacks. Why was the US advance so much less than the German? ... Without some explanation, it seems hard to see how general results on advance distances can be inferred that might be useful in current NATO studies. ... [It is] a pity that the data do not include [defensive posture categorizations such as prepared defence, hasty defence, delaying actions, etc.]. This is a reflection of the difficulty we have felt in handling this excellent data set that there is no tactical information. ... The importance of some measure of relative strengths of the opposing forces is beyond doubt, but there seems to be considerable difficulty in determining what precise form it should take. ... The effects of correlations between adjacent sectors and days should be investigated in the hope that this would account for some of the variability at present unexplained."

8. Comments and Critique:

a. This is an excellent and careful review of the statistical treatment used in the RMC report.

b. Other pertinent references include the following:

(1) Freedman, D. A., "A Note on Screening Regression Equations," The American Statistician, 37, 152-155

(2) Freedman, L. S. and David Pee, "Return to a Note on Screening Regression Equations," The American Statistician, 43, 279-282

BREAKTHRU-1976

1. Document:

- a. Title: A Study of Breakthrough Operations
- b. Author: HERO
- c. Date: October 1976
- d. Organization: Historical Evaluation and Research Organization
- e. Number: AD-A036 492

2. Objectives and Scope:

a. (pg 1, Executive Summary) "The purpose of the study was to examine breakthrough operations in past wars of recent history so as to provide a basic understanding of the essentials of such operations, and to assist those in the nuclear community who are modeling breakthrough operations, as well as those decision-makers who will shape the US capability to defeat a potential breakthrough in conventional or tactical nuclear combat."

b. The operations considered are:

- (1) Megiddo: Breakthrough of the XXI Corps of Allenby's British Expeditionary Force in Palestine, 19-21 September 1918
- (2) Battle of Flanders: Breakthrough on the Meuse by Guderian's XIX Corps of German Panzer Group Kleist, 10-15 May 1940
- (3) Ukraine Invasion: Breakthrough of German First Panzer Group, 21-26 June 1941
- (4) Battle of Jitra: Breakthrough of the Japanese 5th Division in Malaya, 8-12 December 1941
- (5) Leningrad Breakthrough: Operations of the Soviet Second Assault Army, Volkhov Army Group, 12-18 January 1943
- (6) Operation "Citadel": Offensive of German XLVIII Panzer Corps in Southern Sector of Kursk bulge, 4-15 July 1943
- (7) Belgorod-Kharkov Offensive: Operations of the Soviet Fifty-Third Army, of the Steppe Army Group, from the Kursk Salient, 3-11 August 1943
- (8) Operation "Cobra": Breakout of the US VII Corps from the Normandy Beachhead, 24-28 July 1944
- (9) Battle of Mutangkiang: Breakthrough of the Soviet 1st Far Eastern Army Group in Manchuria, 9-15 August 1945
- (10) Korean Offensive: Breakthrough of the North Korean Army to Seoul, 25-28 June 1950
- (11) Sinai Front, Six-Day War: Breakthrough of Tal's Division (Israeli) at Rafah, 5-6 June 1967
- (12) Sinai Front, Six-Day War: Breakthrough of Sharon's Division (Israeli) at Abu Agcila, 5-6 June 1967
- (13) Golan Front, Six-Day War: Breakthrough of Mendler's Brigade (Israeli) at Qala, 9-10 June 1967
- (14) Golan Front, Six-Day War: Breakthrough of Bar Kochva's Brigade (Israeli) at Tel Fahar, 9-10 June 1967

3. Using the Following Data Sources: Quick Wins and other sources.

4. Distance Defined As: Unspecified, but characterized in the table of Figure 2 as "Depth of Penetration."

5. Time Interval Defined As: Unspecified, but characterized in the table of Figure 2 as "Days to Breakthrough."

6. Situational Descriptors Defined As: Numerical manpower ratio, width of front, and several others.

7. Summary of Conclusions Regarding Advances: (pg 12) "An inspection of Figure 2 shows that there is no obvious relationship between the rates of advance and the four different kinds of force ratios shown—numerical/manpower ratio, firepower ratio, combat power ratio, and effective combat power ratio. This bears out the results HERO has obtained in analyses of more than 100 engagements and campaigns of World War II and the Arab-Israeli Wars of 1967 and 1973: no apparent relationship between force ratios and rates of advance."

8. Comments and Critique:

a. The narrative accounts of the action are very good. The one for Operation Citadel (pp 107-198) is particularly detailed and complete. Although the focus of this report is not on advance rates *per se*, the narrative accounts it contains could provide useful additional information to anyone studying advance rates for these operations.

b. This report can be considered as a sequel to HERO's "A Survey of "Quick Wins" In Modern War," which was summarized above as QUICK WINS-1975. Several of the operations studied here are also included in Quick Wins. However, the values cited here are not necessarily the same as those reported in Quick Wins. For example:

Operation	Values in Breakthrough	Values in Quick Wins
Megiddo	$70/2 = 35^*$	$310/14 = 22$
Flanders	$10/2 = 5$	$545/26 = 21$
Cobra	$21/3 = 7$	$880/32 = 28$
Manchuria	$160/8 = 20$	$450/12 = 38$
North Korean Offensive	$50/3 = 17$	$560/42 = 13$
Jitra (Malaya)	$10/1 = 10$	$515/32 = 16$

* $\text{Distance (km)} / \text{Time (days)} = \text{Rate (km/day)}$

There is no discussion or explanation of these differences, although presumably they arise from considering different portions of the campaigns. Since the "days to breakthrough" values tabulated in Figure 2 are usually only a small fraction of the days elapsed from the start to the end of the campaign, it is difficult to tell just what part of the campaign Figure 2 represents.

c. The data for operations 2b(11) through 2b(14) probably is correlated (i.e., partly redundant) information, and should not be considered as entirely independent data points.

d. See the Wainstein paper summarized in our WAINSTEIN-1984 for an informative commentary on the Soviet WW II Manchurian campaign.

SCHÄFFER-1977

1. Document:

a. Title: Zur Ermittlung Funktionaler Zusammenhänge Zwischen Bewegungsgeschwindigkeit und Verlustraten Militärischer Verbände im Gefecht [On the Determination of the Functional Relationship Between Speed of Movement and Loss Rates of Military Units in Combat]

b. Author: Schäffer, Alfred

c. Date: 9 June 1977

d. Organization: Hochschule der Bundeswehr München

e. Number: HSBwM-ID03/77

2. Objectives and Scope:

a. This Diplomarbeit [Thesis] offers an alternative analysis of the RMC data (see our summary RMC-1974). It is limited to the Ardennes data set, since the Lorraine data set contains no German loss data and only sparse information on US losses. (pg 33) "Contemporary military wargames use, among other models, those in which the rate of advance is determined by the attacker's losses. Therefore, ... we here investigate a model in which the speed of movement depends only on the attacker's loss rate."

b. No new historical data is provided.

3. Using the Following Data Sources: Those RMC attack days for the Ardennes Campaign on which data for the attacker's losses are available (a total of 53 attack days, consisting of 14 days of German attacks without US counterattacks, 28 days of US attacks without German counterattacks, 0 days of German attacks followed by US counterattacks, and 11 days of US attacks followed by German counterattacks).

4. Distance Defined As: Same as in the RMC work.

5. Time Interval Defined As: Same as in the RMC work.

6. Situational Descriptors Defined As: Same as in the RMC work.

7. Summary of Conclusions Regarding Advances:

a. For the Germans, advance distances increased with losses. For the US, advance distances decreased with losses.

b. The best fitting model is one involving 17 free parameters. It incorporates terms for attacking infantry platoons per km of front (and its square), defending infantry platoons per km of front (and its square), attacking tanks per km of front (and its square), defending tanks per km of front (and its square), attacking artillery intensity (and its square), defending artillery intensity (and its square), tank mobility, the preparedness of the defender's posture, percent mechanization of the infantry, and visibility as well as a constant term.

8. Comments and Critique:

a. This is an interesting independent and alternative analysis of some of the RMC data from a somewhat different perspective. It illustrates that there are several possible approaches to this data set.

b. The proposed best fitting model is an overfit to the data, and Lindley's cogent criticisms of the RMC report are pertinent here as well (see our summary LINDLEY-1976). However, the author correctly avoids overgeneralizing his findings.

FALLACY-1977

1. Document:

- a. Title: A Fallacy of American Combat Simulations: Rates of Advance Are *NOT* Proportional to Force Ratios
- b. Author: HERO Staff
- c. Date: 1977
- d. Organization: T. N. Dupuy Associates
- e. Number: History, Numbers and War: A HERO Journal, 1(1977), 2(Summer), 105-114

2. Objectives and Scope:

- a. The purpose of this paper is to support its title conclusion that rates of advance are not proportional to force ratios.

- b. The operations considered are:

- (1) ORALFORE data
- (2) Quick Win data
- (3) Breakthrough Study data
- (4) Western Europe WWII data
- (5) Arab-Israeli War data

3. Using the Following Data Sources: The ORALFORE, Quick Wins, and Breakthrough reports, and HERO data bases

4. Distance Defined As: Unspecified, but presumably displacement of the FEBA

5. Time Interval Defined As: Unspecified

6. Situational Descriptors Defined As: Unspecified

7. Summary of Conclusions Regarding Advances: (pg 106) "In past wars there has never been any relationship between rates of advance and force ratios—no matter how force ratios are calculated. Furthermore, there is no logical basis for assuming that there is such a relationship now, or will be in the future."

8. Comments and Critique: This paper ably sets forth the case for its conclusions. The data it presents reasonably adequately support the conclusion stated.

IABG-1978

1. Document:

- a. Title: Auswertung Historischer Konflikte zur Bestimmung von Vormarschräten [Evaluation of Historical Conflict for Determining Rates of Advance]
- b. Author: Böddleker, U. and J. Pantke
- c. Date: 20 April 1978
- d. Organization: Industriebetriebe-Betriebsgesellschaft mbH (IABG), Trier, West Germany
- e. Number: M-ZO 4013/08

2. Objectives and Scope: IABG was tasked in "Vormarschräte Rot" [Red Rates of Advance] to investigate using the EINFALL 75 wargame what average speed of advance should be adopted for Warsaw Pact troops. The results of that investigation were to be compared to those of a parallel empirical analysis of advance rates in WWII. This document responds to the latter requirement with a review of the following five studies:

- a. HERO's ORALFORE study summarized above as ORALFORE-1972
- b. RMC's analysis of the Ardennes and Lorraine data summarized above as RMC-1974
- c. An evaluation of historical conflict by the Societe d'Etudes et Conseils AERO (Paris) as reported in Bresson, M. and L. Bayle, "Analyse Historique et Elaboration des Modeles de Combat," Presented to the NATO/SPOSS Conference in Munich, August 1974
- d. An analysis of rates of advance as reported in "Vormarschgeschwindigkeiten Sowjetischer Panzerverbände [Rates of Advance of Soviet Armor Units]," Staff Paper, G2-Az. 04-04-10, German Second Jäger Division
- e. Jeffrey Record's article summarized above as RECORD-1973

3. Using the Following Data Sources: As in the sources consulted

4. Distance Defined As: As in the sources consulted

5. Time Interval Defined As: As in the sources consulted

6. Situational Descriptors Defined As: As in the sources consulted

7. Summary of Conclusions Regarding Advances: (taken from the study's Summary, pp. 4-7, *passim*) "From the available reports three results and inferences can be set forth:

"a. Regarding the Relation Between Rates of Advance and the Factors Influencing Battle.- A quantitative estimate of the relation between force ratio and rate of advance can only be developed from the data of Operations 5 and 6 [of the ORALFORE report]. From it two inferences can be derived:

- "(1) Rates of advance depend directly on combat power ratios
- "(2) Sustained advances are possible only if the combat power ratio exceeds a certain threshold

"Rates of advance depend rather strongly on the attacker's losses or the combat intensity. The defender's losses appear to have a much smaller effect on the speed of the attack.

"Of the operational variables the following, in order of their importance, exert the greatest influence on rates of advance:

- "(1) Attacker's mission
- "(2) Mission and position of the flanking units
- "(3) Defender's mission
- "(4) Relative combat power of the engaged units
- "(5) Intensity of resistance

"The following environmental variables, in order of their importance, most strongly influence rates of advance:

- "(1) General terrain conditions
- "(2) Weather
- "(3) Significant obstacles (rivers, urban areas, etc.)
- "(4) Road net and road conditions"

"b. Regarding Rates of Advance.- The results of the evaluation make it appear advisable to consider various categories of rates of advance under particular battle circumstances, specifically:

- (1) Category I: Advance Against Resolute Resistance
 - IA: Intense Resistance
 - IB: Moderate Resistance
- (2) Category II: Advance Against Light Resistance
 - IIA: Weak Resistance
 - IIB: Insignificant Resistance
- (3) Category III: Advance Without Resistance
 - Redeployment of units in the battle area without real resistance"

[The report at this point gives a Table and a Figure—not reproduced here—for the rates to be expected under these categories. As I read them, in very simplified general terms they suggest a rate of around 0-5 km/day for Category IA, 5-15 km/day for Category IB, 15-30 km/day for Category IIA, 35-50 km/day for Category IIB, and 50-150 km/day for Category III.]

"The results of the evaluation show that rates of advance against resolute resistance are very low. These results correspond generally with the investigation "Vormarschräte Rot".

"The evaluation showed furthermore that the rate of advance of about 70 miles (112 km/day) postulated in Soviet military doctrine was never achieved in WWII. It appears that Soviet planners have underrated the antiarmor capabilities of the West and the difficulties of the Mid-European terrain.

"c. Regarding the Use of Historical Data as Inputs to Wargames and Simulations. This investigation dealt with a few operations, which were conducted by different combat forces under completely differing conditions. The "indicator" for a particular set of conditions is therefore too limited. Determining the influences of the various interacting and partly contradictory elements would require a substantially larger quantity of data.

"These conclusions can be viewed as a frame, within whose bounds rates of advance can vary. The results of contemporary wargames and simulations can be compared to the values set forth."

8. Comments and Critique:

a. This is an interesting assembly and survey of historical data and analyses of rates of advance compiled from several different and apparently independent sources. It is one of the earliest such that has come to my attention.

b. The IABG report appears to place great weight on the ORALFORE study's findings, but to give them its own emphasis. In particular, the study conclusion given above under 7a(1) seems to be severely at odds with (and may be a misinterpretation of) the conclusions set forth in the ORALFORE report. (See our summary ORALFORE-1972.) It certainly does not reflect Dupuy's position as consistently represented in such works as summarized in BARRIER-1974, QUICK WINS-1975, BREAKTHRU-1976, FALLACY-1977, and others that could be cited.

DUPUY-1982

1. Document:
 - a. Title: Some Facts About Advance Rates in War
 - b. Author: Dupuy, Trevor N.
 - c. Date: November 1982
 - d. Organization: T N Dupuy Associates
 - e. Number: Unpublished
2. Objectives and Scope:
 - a. The purpose of this paper is to present certain propositions and generalizations about advance rates in land combat operations.
 - b. No new historical data are presented.
3. Using the Following Data Sources: None specifically identified
4. Distance Defined As: Unspecified
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As: Unspecified
7. Summary of Conclusions Regarding Advances: (pp 4-8)
 - a. "Advance against opposition requires local combat power preponderance.
 - b. "There is no direct relationship between advance rates and force ratios
 - c. "An "all-out" effort accelerates advance, at a cost in casualties.
 - d. "Advance rates are adversely affected by difficult terrain.
 - e. "Advance rates are slowed by rivers and canals.
 - f. "Advance rates vary positively with the quality and density of roads.
 - g. "Advance rates are adversely affected by bad weather.
 - h. "Advance rates vary inversely with the strength of defender's fortifications.
 - i. "Advance rates are slower at night than in daytime.
 - j. "Advance rates are faster for a force that achieves surprise.
 - k. "Advance rates decline daily in sustained operations.
 - l. "Combat effectiveness superiority of an attacker enhances his advance rate.
 - m. "Advance rates reflect interactions with friendly and enemy missions. ... few commanders have the authority or the opportunity to press an advance without substantial constraints that will inevitably affect the rate of advance."

8. Comments and Critique:

a. This paper presents several intriguing propositions that deserve close attention, further study, and efforts to test, verify and refine them.

b. In their present form, many of these propositions are tautologies exhibiting the vicious circle fallacy alluded to elsewhere. For example, the proposition that advance requires "combat preponderance" is viciously circular unless "combat preponderance" is defined in terms that have nothing *a priori* to do with advancing. But it is difficult, in our current state of knowledge, to imagine any index or measure of "combat preponderance" that has no *a priori* connection or correlation to the capability of advancing against enemy opposition. Similarly, difficult terrain is often recognized by its effect on advance rates, so (circularly) difficult terrain slows advances. The possibility of such circularities can be avoided only by very careful interpretation.

c. As well as being somewhat tautologous, some combinations of these propositions seem mutually incompatible or inconsistent. For example, there is an apparent contradiction between proposition 7a to the effect that a certain force ratio must be attained for advance to be possible, and proposition 7b to the effect that force ratios don't matter. Similarly, propositions 7b and 7l seem mutually contradictory.

d. Little specific evidence for or against the propositions is presented in the subject paper. That was not the purpose of the paper. Presumably they are based on prior studies and the broad experience with a wide range of combat history available to their author. But objective factual support is needed before their exact range of applicability can be determined.

SIMPkin-1984

1. Document:

- a. Title: Red Armour
- b. Author: Simpkin, Richard E.
- c. Date: 1984
- d. Organization: Pergamon Press Ltd, Oxford
- e. Number: ISBN 0-08-028341-1

2. Objectives and Scope:

a. (pg 118, regarding tank force operations) "There was, I found, a good deal of what one might (by analogy with "verbiage") call "figurage" about; but this was so presented as to be almost meaningless and to allow students of Soviet mobile warfare to pluck out and wave about almost any figure that suited their argument at the time. I therefore decided, by a rough analysis of this data, to establish some kind of model for Soviet tank force operations in the Second World War and then to extrapolate forward using yardsticks which were either generally accepted or I reckoned I could justify."

b. The specific operations used are not named.

3. Using the Following Data Sources:

a. Books by Radzievskii and Losik, and key articles by Radzievskii, Cherednichenko, Frolov and Kobrin, and Krupchenko

4. Distance Defined As: Unspecified

5. Time Interval Defined As: Unspecified

6. Situational Descriptors Defined As: The situations considered involve (pg 120) operational moves by tank armies (or in some historical instances tank corps), sometimes accompanied by mechanized corps, sometimes not. Operational moves are controlled movements during an operation, often ordered at the shortest possible notice. In our review we limit attention to Simpkin's discussion of "switches," or repositioning of forces, mainly at night. This is but a fraction of the material addressed in Simpkin's work.

7. Summary of Conclusions Regarding Advances: (pg 120) "But to my surprise [for "switches"] none of the obvious factors—such as day or night, good roads or bad, dry weather or wet, even (as remarked earlier) the number of routes allocated—seemed to make any difference detectable as a pattern by eye, let alone [statistically] significant."

8. Comments and Critique:

a. Simpkin's inveighing against the dangers of "figurage" are well taken.

b. That Simpkin is unable to find any environmental or operational factors affecting rates of advance for "switches" is interesting, for it suggests the conjecture that such factors are of much less importance than might naively be expected. How broadly this finding applies is not known.

WAINSTEIN-1984

1. Document:

- a. Title: Major Front Movements and the Role of Armored Forces
- b. Author: Wainstein, Leonard
- c. Date: June 1984
- d. Organization: Institute for Defense Analyses
- e. Number: IDA Paper P-1784

2. Objectives and Scope:

a. (pg S-1, Summary) "This study examines major campaigns from 1939 to 1973 in order to determine how fast armies have moved and specifically the armored components of them. It has also tried to illustrate some of the factors that influence the advance of armored formations."

b. (pg I-1, Introduction) "An examination was undertaken of the Second World War, Korea, Vietnam, the Indo-Pakistan clashes of 1965 and 1971, and the Arab-Israeli wars of 1956, 1967, and 1973 in order to determine what lessons in these armored operations could provide insights for the future."

3. Using the Following Data Sources: Varied, but for the most part unit histories and other official and quasi-official histories, supplemented by books, articles and reports by reputable military historians.

4. Distance Defined As: (pg II-1) "Nevertheless, it should be stressed that measurement of map distances with dividers is obviously a form of macro-measurement. There can be no claim to precision but, on the other hand, the distances are reasonably accurate. Because the even 'smoothed' FEBA exists only in the model builder's imagination, it often becomes difficult to decide the point of maximum forward movement. Some degree of judgment by the analyst has therefore been necessary."

5. Time Interval Defined As: Unspecified

6. Situational Descriptors Defined As: (pg II-1) "Each campaign is described in terms of date, duration, maximum front movement, and average miles per day from start point to the point of maximum penetration. The phasing of individual campaigns is also to some degree artificial, but the source texts present them in this fashion." Occasional (but rather general) remarks about the nature of the terrain, bottlenecks, degree of opposition, etc. are provided in the accompanying discussion.

7. Summary of Conclusions Regarding Advances: (pp VI-1 to VI-7. Some Summary Observations)

a. "Ideally, in terms of our specific interest, causation in battle would be established by determining the relative weight of the factors affecting advance rates as suggested in the two listings [of such factors] in this paper. However, the existing historical record does not permit such completeness since much of the data we would like are irrevocably gone."

b. "The circumstances of campaigns and of battles within campaigns are sufficiently diverse as to make derived 'averages' tenuous as mathematical tools, yet they do provide a scale for purposes of comparison. The analysis in this paper does indicate that daily rates of advance in campaigns of any duration tend to be rather small. ... Longer campaigns have pauses when advancing forces must carry out interim

consolidation, regroup units, replenish supplies, and re-order logistic tails. ... What is significant, however, is that [initial or surprise attacks, which have the highest advance rates] had to penetrate only a very lightly fortified enemy frontier or line, if indeed it was fortified at all. For all other cases, the daily average advance rate drops sharply. Even for initial attacks, the rate of advance after the first few days tended to slow."

c. "Some of the more notable [factors other than enemy opposition that slow advances] ... are repeatedly mentioned in unit records or histories. The impact of these is probably inherent in any armored operation. ... They are not, however, discussed in any order of importance. [Those specifically pointed out are as follows.]

(1) "Well fortified and defended positions. ... Armor made its spectacular advances in exploitation and pursuit [not frontal attacks of heavily fortified areas]. ... Yet the First US Army statistics offered in this paper show that it was involved in pursuit only 22 percent of the time. The 64 percent of its combat time spent on offensive operations yielded only modest average daily advances."

(2) "Obstacles. ... Far less predictable and thus more dangerous [than natural and hence predictable obstacles] because of their randomness are the man-made obstacles that the enemy can emplace. ... [Another form of obstacle is] the self-made one created by one's own supporting artillery or air attack."

(3) "Congestion. Except in Russia and the desert, congestion has been a problem when large armored forces are in action. ... Whenever armor is constrained, whether by hedgerows as in Normandy, by rivers, towns, minefields, and cannot circumvent the choke point, congestion tends to occur."

(4) "Logistic Constraints. [Fuel and POL supplies are critical. The Line of Communication becomes badly strained as forces move further and further from their initial bases.]

8. Comments and Critique:

a. This paper very ably responds to its stated objective. It contains a wealth of data not readily available from any other source, and gives a very cogent discussion of the major factors bearing upon advances by large armored units.

b. (pg II-24) "[With regard to information in The West Point Atlas of American Wars and in Ziemke, Earl F., Army Historical Series, 'Stalingrad to Berlin: The German Defeat in the East,' Office of Chief of Military History, Dept. of the Army, Washington, DC, 1968] Where they overlap in time ... the data are noticeably different. However, both are reliable sources and no attempt at reconciliation of the data will be attempted."

c. This paper, on pp II-30 to II-34, provides a very informative discussion of the Soviet WW II Manchurian campaign. In particular it points out that the Japanese forces were "little more than a hollow shell," outnumbered by 416,000 to 72,000 in terms of troops in combat units, with half the authorized number of machine guns and no anti-tank weapons, and short of artillery and ammunition. The whole campaign was conducted after the atomic bombing of Hiroshima (6 August) and Nagasaki (9 August). "The Sixth Guards Tank Army met no resistance at all for the first four days [9-13 August 1945] and virtually none in the whole campaign. The two mechanized corps [accompanying it] used extended march order, each in six to eight parallel columns. ... Japanese forces had begun to surrender on 15 August in response to the Emperor's declaration of the war's end. The Soviets for obvious political purposes refused to accept the 15 August surrender, thereby continuing their advance to reach their set territorial objectives, ... They accepted only the 2 September surrender in Tokyo harbor."

ANTHONY-1987

1. Document:

- a. Title: The Applicability of Fractal Distributions and Scaling Laws to Representations of Warfare Data
- b. Author: Anthony, Robert
- c. Date: 1 March 1987
- d. Organization: Institute for Defense Analyses, 1801 North Beauregard St., Alexandria, VA 22311
- e. Number: Unpublished manuscript

2. Objectives and Scope:

- a. The aim is to show that a significant body of data on military affairs is consistent with being fractal, and to offer ways to represent military statistics that take this possibility into consideration.
- b. The data used are taken from the data sources used, as listed below.

3. Using the Following Data Sources:

- a. Data on deaths in war from Richardson, Lewis Fry, "Statistics of Deadly Quarrels," Boxwood and Quadrangle Press, Monterey, CA, 1960
- b. Durations of Eastern Front Campaigns (source unspecified)
- c. Durations of Western Front Campaigns (source unspecified)
- d. V Corps Command Post Moves from Wainstein, Leonard, "Major Front Movements and the Role of Armored Forces," Paper P-1784, Institute for Defense Analyses, June 1984
- e. Wainstein's data on Normandy-Northern France and Siegfried Line battles in WWII (summarized as WAINSTEIN-1973a)
- f. Division days in combat in NW Europe in WWII (unspecified, but possibly from Beebe, Gilbert W. and Michael E. De Bakey, "Battle Casualties," Charles C. Thomas, Publishers, Springfield, Illinois, 1952)
- g. McFarlan, Donald, and Norris D. McWhirter (eds.), "Guinness Book of World Records," Sterling Publishing Co, Inc., New York.

4. Distance Defined As: Whatever was used in the source

5. Time Interval Defined As: Whatever was used in the source

6. Situational Descriptors Defined As: Situational descriptors not used

7. Summary of Conclusions Regarding Advances: Adduces some evidence that the distributions of times may be Pareto distributed, i.e.,

$$\text{prob}(x) = k(1/x)^{\text{power}}$$

where the power must be at least 1 if the probability distribution is to integrate to a finite value, for otherwise the normalizing constant k is not defined.

8. Comments and Critique:

a. This paper presents a fascinating approach based on recent developments in fractal analysis. It is the first systematic attempt I know of to apply these new methods to problems of military historical analysis.

b. However, I do not believe that Anthony presents enough evidence to carry the day for his conjecture that the distribution is Pareto. That doesn't necessarily mean the conjecture is false. But until more supporting data is presented the issue will remain open.

c. (pg 46) Anthony observes that the Germans chose rough terrain to make their defensive stands. If so, then terrain roughness and rate of advance become confounded through the common operation of this mechanism.

DUPUY-1987

1. Document:
 - a. Title: Can We Rely Upon Computer Combat Simulations?
 - b. Author: Dupuy, Trevor N.
 - c. Date: August 1987
 - d. Organization: Armed Forces Journal International
 - e. Number: August 1987, pp 58-63
2. Objectives and Scope:
 - a. This article raises questions about the validity of the assumptions in certain US Army wargames.
 - b. The data used are those in the HERO land warfare data base, which is also in use at CAA under the name Combat History Analysis Study Effort (CHASE) Data Base, or CDB for short.
3. Using the Following Data Sources: HERO/CDB data base
4. Distance Defined As: Unspecified
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As: Unspecified
7. Summary of Conclusions Regarding Advances: (pg 63) "Thus, the weight of the data from 601 battles since 1600 strongly suggests that there is no direct relationship between strength ratios and either advance or attrition rates. It is clear that increasing the strength of the stronger force in a battle is not likely to increase either its attrition-causing capability, or its rate of advance."
8. Comments and Critique: This is an interesting and provocative article. A sharp rebuttal to it appeared in the following issue of Armed Forces Journal. Nevertheless its main conclusion regarding rates of advance seems to be well supported by the evidence it presents.

1. Document:
 - a. Title: The Pace of Operations: Maximum Rates of Advance
 - b. Author: Rowland, David, and David Watson
 - c. Date: April 1988
 - d. Organization: Defense Operational Analysis Establishment (UK)
 - e. Number: DOAE Working Paper 670/7
2. Objectives and Scope:
 - a. To define the upper limits of advance rate for unopposed movement
 - b. Data on a wide variety of operations including several from the 19th Century, the Boer War, WWII, the Falklands War of 1982, and others too numerous to name.
3. Using the Following Data Sources: Varied, and for the most part not explicitly cited.
4. Distance Defined As: Unspecified
5. Time Interval Defined As: Unspecified
6. Situational Descriptors Defined As: Unspecified
7. Summary of Conclusions Regarding Advances: (pg 15)
 - a. "Unopposed rates of advance vary with the number of days duration of advance; advances on the best one third of individual days being 50 percent higher than the sustained average. There was often a pattern of two days advance with one days rest, or short advance, in three day cycles."
 - b. "Non-mechanised advances on roads average about 16 miles/day; advances on the best days achieving 23 miles on flat ground."
 - c. "Non-mechanised advances over hilly ground reduce the above by a factor

$$(1 - e^{-50/h})$$
 where h is mean ridge height in meters; this reduces the 16 miles/day to 6.4 miles/day over 100 meter ridges and below 2 miles/day over 400 meter ridges."
 - d. "Mechanised advances on roads average about 35 miles/day, advances on the best days achieving 50 miles for typical armoured division wheel/track mixes and a preponderance of vehicles with 25 mph maximum speed. A preponderance of vehicles of different maximum speeds will change this proportionately with the maximum vehicle speed. Generally, sustained daily speeds will represent 1.4 hours at maximum vehicle speed, with best days representing about two hours at the maximum vehicle speed."

8. Comments and Critique:

a. This paper ably responds to its stated objective of determining the upper limits on rates of advance by unopposed forces. The present paper is a preliminary or working paper, so its findings may be modified in the final version. But it contains a wealth of data not readily available from any other source.

b. I must confess I do not myself see in the data very strong support for the three day cycle proposed by this paper. It may be there, but the support for it seems rather weak to me. Also, some Monte Carlo experiments with distributions having about the same coefficient of variation as these data show that a random sample of three points will on the average have a mean about $2/3$ the maximum of the three-point sample. So the meaning of "Rowland's Law" (that the mean three-day advance is about $2/3$ the maximum) is uncertain. It may be that a Fourier time-series or autocorrelation analysis would highlight the postulated pattern of two day's advance followed by a day's halt or leisurely advance. Also, recall that Clausewitz alludes to a 3-day cycle of this type (see our summary CLAUSEWITZ-1832).

c. I also have my doubts as to the validity of the conclusion regarding the relation between rates of advance and the maximum speed of major vehicles. My uneasiness arises from the fact that the average daily advance rate is but a small fraction of the maximum vehicular speed. Hence, I suspect that factors other than the maximum vehicular speed govern average daily advance rates, and so expect that changes in maximum vehicular speed to have little influence on average daily advance rates.

d. Note also that Clausewitz's factor for slowing over mountains seems to produce much less degradation than that adopted by Rowland (compare with our summary CLAUSEWITZ-1832).

CAA-RP-90-03

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APPENDIX B
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<u>Volume no.</u>	<u>AD number</u>
1	B086 797L
2	B087 718L
3	B087 719L
4	B087 720L
5	B087 721L
6	B087 722L

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A SURVEY OF PAST WORK ON RATES OF ADVANCE IN LAND COMBAT OPERATIONS

SUMMARY
CAA-RP-90-3

THE REASON FOR PERFORMING THIS STUDY was that a short but systematic basic reference paper surveying and reviewing the current state of the art is needed to provide a sound basis for contemporary and future work on rates of advance. Unfortunately, the literature on the quantitative analysis of rates of advance is widely scattered and often hard to find. We are not aware of any other work that covers this area as thoroughly as this Research Paper does. As such, it furnishes a valuable orientation and point of departure for further work in this important field of investigation. It is hoped that wide dissemination will stimulate further research and study of the fundamental issues it raises.

THE STUDY SPONSOR was the Secretary of the Army. This is the first paper to be prepared under Dr. Robert L. Helmhold's Secretary of the Army Research and Study Fellowship, and others addressing the rate of advance data and its quantitative analysis are planned.

THE STUDY OBJECTIVE was to provide a critique and comparative survey of some of the noteworthy past quantitative analyses of the principal factors governing rates of advance in land combat operations.

THE SCOPE OF THE STUDY was intended to be comprehensive, in the sense of including all of the noteworthy work in this area. It is, no doubt, too much to hope that literally every work was indeed identified in time to be included. Nevertheless, this survey does provide an excellent overview of the current state of the art. Over 30 past works are summarized in Appendix A and reviewed in Chapter 2.

THE MAIN ASSUMPTION of this paper is that no work that would substantially alter the principal findings remains unknown.

THE BASIC APPROACHES used in this study were:

- (1) To obtain through extensive personal visits, correspondence, and phone calls all of the noteworthy quantitative analyses of rates of advance, and then to
- (2) Study, analyze, critique, and comparatively review these documents.

THE PRINCIPAL FINDINGS of this work are:

- (1) The literature is filled with controversy, reverberant with strong claims and counterclaims, few of which—despite being strongly held opinions—can muster in their support more than the weakest of evidence. There is a need for a more balanced and cool-headed view of the situation.
- (2) Past work often overgeneralizes and overextrapolates its conclusions far beyond what is reasonably supportable by its slender basis in historical fact.
- (3) Highly questionable statistical practices are often employed. Specifically, these involve blind "data-dredging," excessive overfitting, and naive application of powerful but delicately sophisticated techniques.

(4) The current state of the art suffers from inadequate appreciation for and attention to the subtle and thorny scientific, methodological, and epistemological problems and issues that must be borne in mind to achieve the best results in this field.

(5) Appreciable difficulties for future quantitative work have been created by the use of subjective/qualitative descriptors not defined in terms of objectively measurable quantities (e.g., the use of such subjective/qualitative descriptors as "intensity of enemy opposition," "degree of difficulty of the terrain," and the like).

THE STUDY EFFORT was directed by Dr. Robert L. Helmbold, Office, Special Assistant for Model Validation

COMMENTS AND SUGGESTIONS may be sent to the Director, US Army Concepts Analysis Agency, ATTN: CSCA-MV, 8120 Woodmont Avenue, Bethesda, Maryland, 20814-2797.